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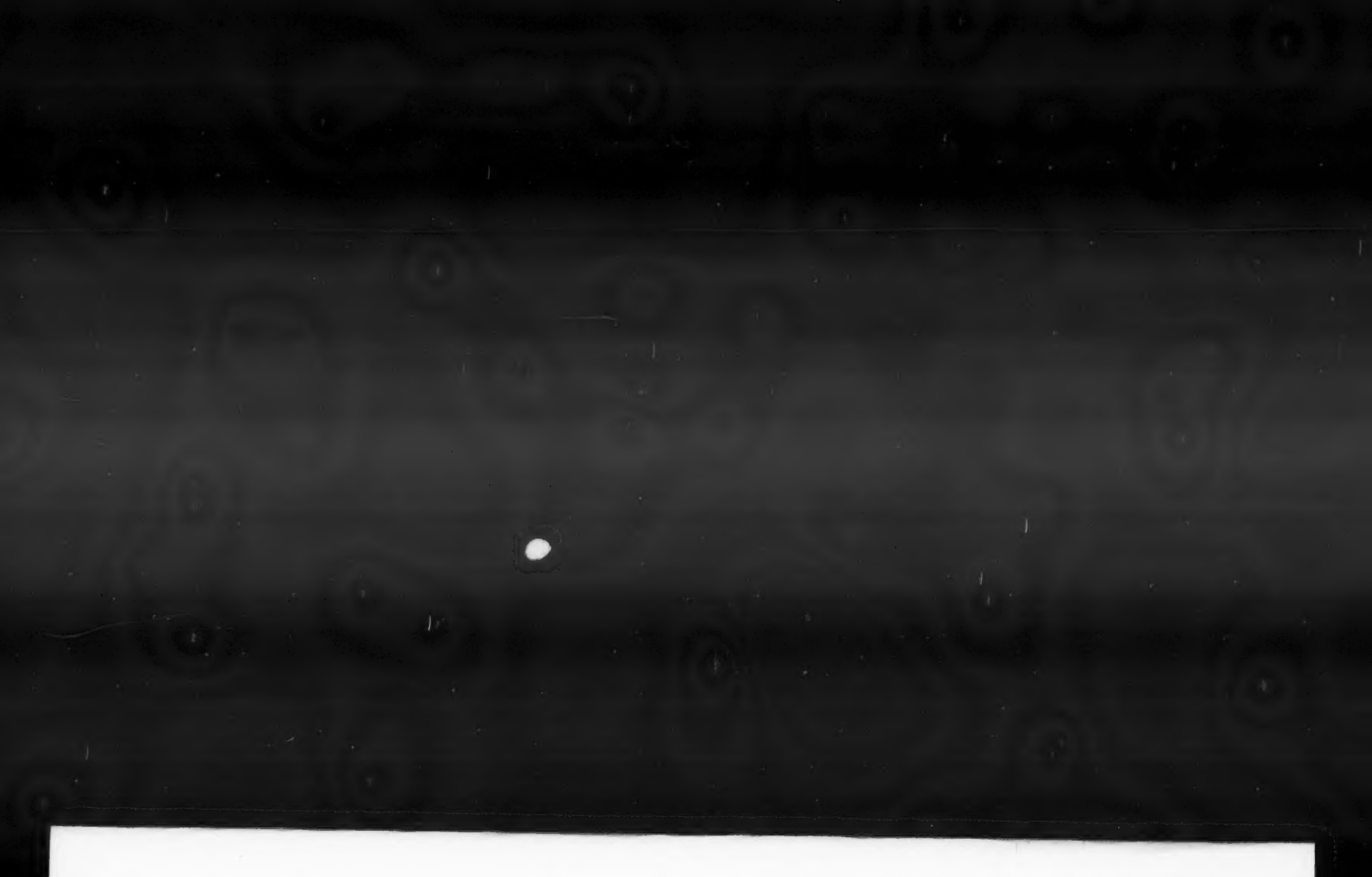

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The Sun

Although relatively unimportant in the universe as a whole, for us, denizens of the earth, the sun is more important than all the rest of the universe. It can not be said with propriety that it is more important than the earth itself, neither can it be said that it is less so. The two jointly constitute a milieu which is favorable to man's existence. Laying aside all considerations of adaptation and of teleology, and accepting conditions as they are, we can assert with complete assurance that the sun is a *sine qua non* for the continuance of the human species, and, indeed, of any of the living species.

We have been accustomed to say that the sun sends the earth heat, light, and energy. In view of recent theory, this statement is tautological. The idea is completely expressed in saying that the sun furnishes the earth with *energy*, of which, to be sure, there are various forms.

It is easy to trace a given form of energy, say electricity, back through the dynamo, the steam, the coal, the growing vegetation; or, perchance, back through the dynamo, the water fall, the rain, the evaporation, to the ultimate source, the sun. In fact, it is impossible to arrive at any other source through such a process of thought.

If, then, primitive peoples are overcome with terror at the prospect of having the sole source of life-sustaining qualities devoured by a dragon, as at the time of an eclipse, it must not be ascribed to ignorance but rather to a deep and convincing realization of fundamental fact.

Nor can the sun-worshippers throughout the ages be said to have worshipped unworthily.

Radial Velocities from Objective Prism Spectra

By S. W. McCUSKEY

Since the time of Sir William Herschel our knowledge of the structure and motion of the great galactic system, at least in the neighborhood of the sun, has increased many fold. Many types of observational data relating to individual stars, such as parallaxes, proper motions, radial velocities, spectra, etc., have played a part in this advance. For the brighter stars ($M<6.0$) these data are quite complete, and therefore the dynamics of the stellar system nearby may be studied in some detail. In the case of the fainter stars ($M>6.0$), however, the investigator of the galaxy finds himself handicapped in many ways by a lack of sufficient data. Among the problems of current interest, the radial velocities for large numbers of faint stars play an important role, and it is the purpose of the present discussion to call attention to these problems in a brief way, and to indicate recent developments in the technique of obtaining the requisite data.

The galaxy, or universe, to which the sun belongs, has been recognized for many years as a large watch-shaped agglomeration of stars, clusters, and nebulae. Its highly flattened shape, indicated by the great increase in the numbers of stars toward the Milky Way, and the irregularities in the star clouds of this belt have suggested the similarity between our own galaxy and the millions of external galaxies, or spiral nebulae. Shapley has found from his studies of globular clusters that the center of this galactic system lies at a distance of some 35,000 light years from the solar system, in the direction of the constellation Sagittarius, a region thickly populated with star clouds. The globular clusters appear to form outposts marking the boundaries of the system.

One look at the spiral arms of an external galaxy is sufficient to suggest that the whole structure is rotating about an axis perpendicular to its plane. Naturally the question arises, is our own galaxy rotating about its axis?

In 1926 and 1927 Lindblad, from theoretical considerations, and Oort, from the observational standpoint, found evidence for the belief that such a rotation does exist in the galaxy. Lindblad's theory indicated that the rotational effect, as evidenced in the radial velocities of the stars near the sun, should be proportional to the distances of the stars observed. Furthermore, in Aquila and Canis Major (galactic longitudes 10° and 190°) the distant stars should show a predominant velocity of recession, while in Cassiopeia and Centaurus (longitudes 100° and 280°) the average radial velocity would cause the stars to approach the sun. Toward and away from the galactic center and for regions in Cygnus and Carina (longitudes 325°, 145°, 55°, 235°) the average

radial velocity should be zero. It is assumed, of course, that the radial velocity due to the sun's motion has been properly allowed for, the above effects being concerned only with the peculiar radial velocities of the stars.

Oort's study of the available radial velocities of the most distant objects, such as the B and O stars which are so luminous as to be visible at great distances, revealed precisely the peculiarities predicted by Lindblad's theory. The very existence of such variations of average radial velocity, interpreted on the rotation theory, implies that the galaxy is not rotating as a solid body, a wheel for example, but that each star is pursuing its own orbit about a distant massive nucleus in much the same way as the planets move about the sun. The stars closer to the center than the sun move faster and must be out-running the sun. Those farther from the center are being left behind.

Such disparity in the orbital speeds of the stars means, of course, that any large and fairly compact grouping of stars, like the Hyades, would be split apart and scattered in a few billions of years. The very presence of these clusters casts some doubt on the interpretation of the observed radial velocity effects as due to galactic rotation.

In order to clarify our ideas concerning this rotational hypothesis, more data are necessary. The task confronting the astronomer at present, therefore, is to secure as soon as possible many radial velocities of faint ($M_{ptg} = 10\text{-}11$) early type, and hence distant stars, particularly in the southern hemisphere. By a method to be described presently it now seems possible to secure radial velocities for great numbers of A and B stars in a reasonably short time, and hence before many years we may be able to say more definitely whether the observed effect is actually due to rotation of the galaxy or to some other cause. To this end an observational program[1] undertaken for a study of galactic rotation is now in progress at the Harvard College Observatory. It calls for the determination of radial velocities by a mass production method for several hundred stars in each of twelve fields distributed uniformly in galactic longitude along the galactic equator.

No less important than the galactic rotation problem is the question of determining the sun's velocity in space relative to the faint stars, a quantity which is essential in finding the mean distances of these stars. For the brighter stars, which are generally the closer ones, individual distances can be determined either trigonometrically or spectroscopically. But for the fainter stars of the galactic system only the mean parallax or distance of a group can be determined. This is done by a comparison of their proper motions with the sun's linear motion in kilometers per second, and hence the latter must be accurately known if mean parallaxes are to be of value for studies of galactic structure.

Relative to the brighter stars the sun is known to have a speed of 20 km/sec. For the fainter stars, however, there seems to be some evi-

[1] For details see Bok and McCuskey, *H. A.* 105 (in press).

dence that the speed is different. How much different is still uncertain. The answer may be given when we know the radial velocities for large numbers of the faint stars.

Among the many other problems now demanding more extensive radial velocity data may be mentioned the asymmetry among the velocities of the fast moving stars, the actual velocity dispersion for the fainter stars, and the high latitude problems connected with the determinations of the gravitational attraction of the galactic system. In all such statistical investigations the emphasis may be put on obtaining large quantities of radial velocity data perhaps at a sacrifice of accuracy in the individual determination. The radial velocities themselves need have an accuracy no greater than the random motions of the stars themselves. Probable errors of ± 10 km/sec are quite acceptable and do not seriously impair the statistical value of the results. By careful control it has been found possible to obtain this accuracy in the use of objective prism spectra for radial velocity determination. But before describing the method employed for this work it may be well to review briefly the historical development underlying present day radial velocity observation.

Nearly a century ago Christian Doppler enunciated the principle, so familiar to all, that the change in pitch of the sound emitted by a moving source was due to the increase or decrease of the frequency with which the sound vibrations reached the ear of the observer. Reasoning analogously for the case of light, he concluded that the frequency of light waves striking the eye should behave in the same way—i.e., the frequency would increase if the observer and the source were moving toward each other, and would decrease if the observer and the source were separating. It remained for Fizeau, however, to show in 1848 how this principle could be applied to the determination of the line of sight motions of the stars.

Fizeau indicated theoretically how the entire spectrum, Fraunhofer lines included, would shift toward the red end of the spectrum if the source of light were moving away from the observer, and toward the violet if the source were approaching. His ideas, though correct theoretically, were impractical for observational use and caused scarcely a ripple on the astronomical trend of thought of that time. It was not until 1871 that Vogel clearly demonstrated the validity of the Doppler-Fizeau principle by observing the rotation of the sun spectroscopically.

In spite of the remarkably accurate measurements of the radial velocities of Arcturus, Aldebaran, and Betelgeuse made by Keeler at the Lick Observatory in 1890, and his contributions regarding the velocities of bright nebulae in the ensuing two years, it was soon evident that the task of measuring the radial velocities of many stars visually was hopeless. Keeler did much, however, to maintain enthusiasm in the problem, and, with photographic methods on the rise, really accurate results were soon forthcoming from several investigators.

The newly invented dry plate photography enabled Vogel and Scheiner at Potsdam to measure the radial velocities of fifty-one stars during the interval 1888-1891, with a probable error of ± 2.6 km/sec. While such accuracy was most encouraging at that time, the results were subject to a considerable systematic error.

It may be said that the accurate methods of determining the line of sight motions of the stars, as we know them today, were inaugurated by W. W. Campbell in 1895. Using the Lick 36-inch refractor and a well-designed spectrograph, Campbell developed the technique and began the observations which have contributed so much to our knowledge of radial velocities. Not only were the accidental errors obtained by him exceedingly small (p.e. ± 0.5 to ± 0.25 km/sec) for the majority of the stars observed, but the systematic errors were negligible. In 1928 the fruits of many years of work by himself and his colleagues in California and in Chile were presented in a catalog[2] of the radial velocities of stars brighter than $M = 5.51$ for the entire sky.

At present, of course, several observatories are engaged in work of this type. Some have chosen special classes of stars for observation; all are advancing from the brighter stars, for which our knowledge of radial velocities is fairly complete, to fainter and fainter ones. An approximate survey of existing radial velocity catalogs reveals that today the astronomer, wishing to make a statistical study of the dynamical problems of the stellar universe, has at his disposal about 8,000 radial velocities, of which perhaps twenty-five per cent are for stars fainter than the seventh magnitude. When the observational programs now under way at many observatories (Lick, Mount Wilson, Dominion Astrophysical, Yerkes, and others) are completed, the radial velocity data relating to stars of magnitudes seven to eleven will be considerably enhanced, perhaps by some two or three thousand stars. It still remains a question, however, whether the general methods of observation now in use are adequate to supply in a reasonable time the large mass of data required.

While very high precision in the observation of radial velocities has been obtained by the use of the slit spectrograph, it has two serious disadvantages which impair its usefulness for the fainter stars: (1) only one star can be observed at a time; (2) long exposures and rather large telescopes are required in order to record the spectrum satisfactorily. If it requires an exposure of one to three hours (depending upon observing conditions) to obtain the spectrum of a tenth magnitude star with sufficient dispersion for good radial velocity measures, it is apparent that the number of radial velocities determined per year will not be very great.

Fifty years ago E. C. Pickering[3] suggested a method of measuring wave-lengths, and hence spectral line displacements, which avoids these

[2] *Lick Publ.* 16, 1928.

[3] Henry Draper Memorial First Annual Report, 9, 1887.

difficulties. If a large prism is placed in front of the objective of a photographic telescope, each stellar image, instead of appearing as a point on the photographic plate, will be a spectrum. Since the stars are in effect point sources of light at great distances away, the light rays entering the telescope are parallel, and hence the slit and collimator of a slit spectroscope are eliminated. The loss of light ordinarily suffered by passage of the rays through the slit is no longer present and therefore much fainter stars can be photographed in the same exposure time. Moreover, all of the stars in the field of view of the telescope appear simultaneously as spectra on the same plate. As many as two or three hundred spectra may be obtained with the same expenditure of telescope time as for one star of equal brightness with the slit spectrograph.

The essential disadvantage in using spectra obtained in this way for radial velocity measurement is the difficulty of obtaining a satisfactory terrestrial comparison spectrum. Since in the use of an ordinary spectroscope the slit defines the spectrum, it is only necessary to flash an iron spark in front of the slit to place on each side of the stellar spectrum a reference system. When the objective prism is used, however, this method is not feasible. Several investigators have overcome the difficulty to some degree by interposing a selectively absorbing filter of liquid or gaseous nature just in front of the photographic plate. Such a filter produces a few additional absorption lines in the spectrum of each star. Since the number of lines introduced in this way must necessarily be small, the precision obtained will not be as great as for the slit spectra.

Although many suggestions and methods[4] have been put forward for adapting the objective prism spectra to radial velocity measurement, no one has actually collected enough homogeneous data to test fairly the usefulness of the procedure already suggested. During the past two years, however, renewed efforts have been in progress at the Harvard Observatory for giving the most promising objective prism methods a thorough trial. Preliminary results indicate that the method described below is capable of yielding satisfactory results. Hence the present aim is to determine perhaps five thousand radial velocities in this way and apply them first to a study of galactic rotation, as mentioned previously. For such a statistical investigation results having probable errors as large as ± 10 km/sec are acceptable, but the system of velocities as a whole must agree with that determined with the slit spectrograph.

The Observational Technique.—Hale and Wadsworth[5] in 1896 proposed the so-called reversion method for measuring radial velocities from objective prism spectra. In principle it was quite simple. Two telescopic exposures were taken either on the same or on separate plates, one with the objective prism so arranged that, say, the blue ends of the

[4] For a complete description of methods and a discussion of comparative results to 1931, see P. M. Millman's article in the *Journal of the Royal Astronomical Society of Canada,* September, 1931.

[5] *Ap. J.,* **4**, 54, 1896.

spectra were to the south, and the other with the telescope or prism reversed so that the blue ends were to the north. Measurements of corresponding pairs of lines in the two spectra of the same star then yielded a quantity which could be referred to the mean of similar quantities for all stars on the plate as a radial velocity relative to the group as a whole. Absolute radial velocities were obtained if there were one or more images of stars with known velocity among those measured. Other methods for setting this zero point were also suggested, but unfortunately they were so uneconomical of light that they proved impracticable.

Some years previously E. C. Pickering[6] had suggested the use of an absorbing screen to be placed before the plates to impress upon each stellar spectrum a reference absorption line or lines from which absolute radial velocity displacements could be measured. After many trials R. W. Wood,[7] working at Pickering's instigation, found that an aqueous solution of neodymium chloride provided a narrow absorption line at λ4272.9 which remained sufficiently sharp over a considerable temperature range to provide the necessary standard. Indeed, this neodymium band is only 3 A. wide and is usually much sharper than the hydrogen lines in the spectra for which it serves as a reference line. One of the chief disadvantages in the use of the neodymium chloride screen, however, is the fact that the wave-length of the principal line, λ4272.9, is very nearly the same as the wave-length of the iron lines at λ4271.5, which become quite strong in the late type stars. Since the spectra used are of relatively low dispersion, the resulting blend would cause systematic errors in the measured velocities for these stars. Hence it has been necessary, at least for the present, to confine observation to stars with spectral type earlier than and including G0.

Inasmuch as Schwarzschild[8] had demonstrated in 1913 the feasibility of using a combination of the above methods with a high degree of success, it was decided to follow the same line of attack in the present investigation. Certain modifications, however, were necessary.

It is apparent that the reversion method as first outlined is very uneconomical of telescope time. Two exposures must be made for each star field, and the likelihood of atmospheric and temperature changes, particularly for long exposure times, is great. Also, the number of fields which may be covered in a given season of observing is seriously restricted.

To eliminate this difficulty a so-called "photographic reversion method" has been devised. A single exposure with the telescope and objective prism is taken, and from this negative two identical contact positives are made. The reversion of one spectrum relative to the other is then accomplished in the measuring comparator, as one may see by

[6] Henry Draper Memorial First Annual Report, 9, 1887; also *H. A.*, 26, XX, 1891.

[7] *Ap. J.*, **31**, 376, and 460, 1910.

[8] *Potsdam Publ.* 69, 1913.

looking closely at the plates shown ready for measurement in Figure 2. Not only is the actual telescope time required to cover a given area diminished by this method, but the increased contrast of the positives enhances the accuracy of setting on a spectral line. No appreciable error has been found by using positives in place of the original negative.[9]

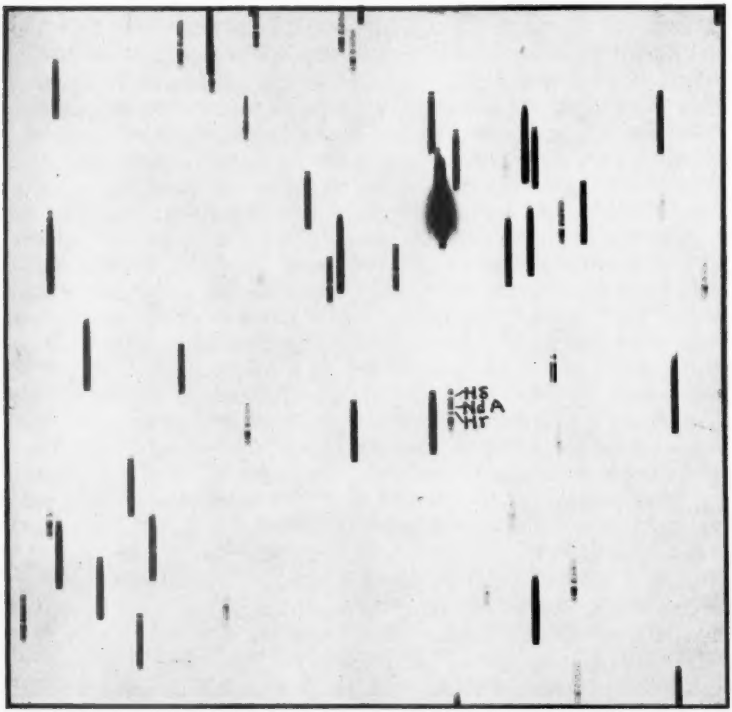

FIGURE 1
TYPICAL OBJECTIVE PRISM SPECTRA USED FOR RADIAL VELOCITY MEASUREMENTS OF STARS IN TAURUS.

Inasmuch as the telescope used has a vacuum plate chamber whereby the plate may be curved to fit the focal surface of the lens, the spectral images are usually well defined nearly to the plate edges. An area of the sky four by four degrees is, however, the limit covered by a single plate. In the Milky Way there may be as many as two hundred images measurable on one plate.

[9] Evershed has employed a similar scheme of using positive on negative for measuring minute shifts in the solar spectrum. See *Kodaikanal Obs. Bull.*, 32, 1913.

For the northern sky the observation of radial velocities from objective prism spectra is being conducted at the Oak Ridge Station of the Harvard Observatory with the 16-inch Metcalf refractor and a 12° objective prism of eleven inches square aperture. A liquid filter consisting of neodymium chloride in water is placed like an ordinary color filter directly in front of the photographic plate. The spectra obtained with this combination of telescope and prism have a dispersion of 92 A/mm at $H\gamma$ and are well suited to the radial velocity measurement. With Cramer HiSpeed plates and an exposure of two hours it is possible to obtain measurable spectra for stars of photographic magnitude 10.2, and sometimes fainter. A typical plate has been reproduced in Figure 1, and the neodymium chloride lines have been indicated on one of the spectra.

Due to the lack of large telescopes in the southern hemisphere, radial velocity determinations for southern stars have lagged far behind those for the northern sky. The present program, however, is to include a campaign in the south, and the observational work is being done through the coöperation of Dr. J. S. Paraskevopoulos at the Boyden Station of the Harvard Observatory, at Bloemfontein. A 6° prism is used there in conjunction with the 13-inch Boyden refractor and neodymium chloride screen in much the same manner as already described.

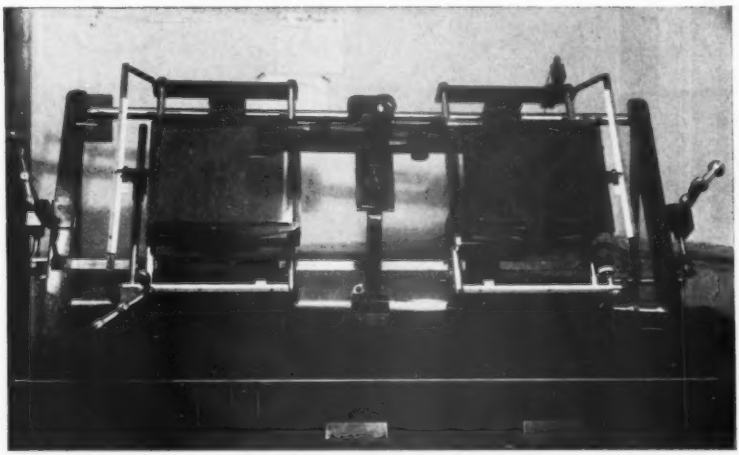

FIGURE 2
THE MEASURING SPECTROCOMPARATOR.

Figure 2 presents a general view of the spectrocomparator designed particularly for the present investigation. It is of the Hartmann type, modified so as to hold two eight by ten plates. A partially silvered prism in the eyepiece is so arranged that the images from the two plates may be viewed at the same time. With coarse rapid motion screws the ob-

server may place in the field of view the images of a given star from both plates, and then accurate differential movement of one spectrum relative to the other is made with the micrometer screw shown at S. A detailed description of the instrument and its use may be found elsewhere.[10]

The process of measurement consists in determining the length of spectrum between the neodymium reference line, NdA, and the stellar lines Hγ and Hδ. The two spectra of the same star are placed in the field of view by means of the coarse screws so that their Hγ lines are nearly coincident. Then the right hand positive (Fig. 2) is moved by

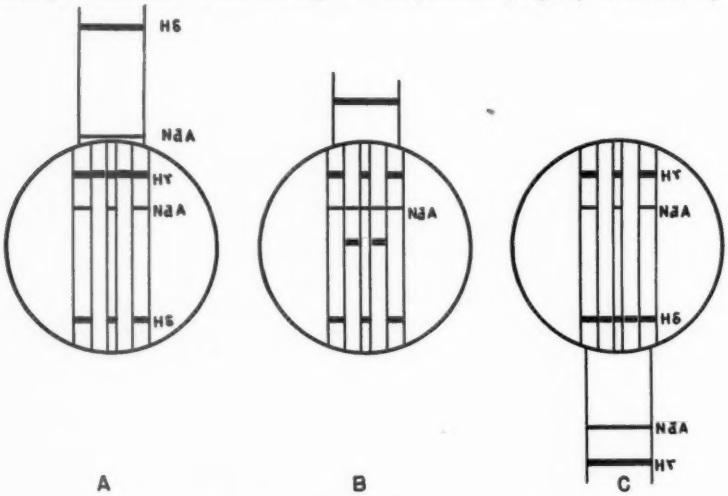

FIGURE 3

ILLUSTRATING THE PROCEDURE OF MEASUREMENT.

A, B, and C represent successive alignments of the Hγ, NdA, and Hδ images. Length of spectrum Hδ to NdA is one half the difference in micrometer readings for positions B and C.

the micrometer screw, and readings are taken as the Hγ, neodymium, and Hδ lines are successively aligned. Obviously the differences between micrometer readings for the stellar lines and for NdA give a measure of twice the spectral length. Figure 3 illustrates the method of measurement.

Several advantages of this procedure may be mentioned, viz., (1) the use of identical images of the broad hydrogen lines reduces setting errors to a minimum; (2) twice the length of spectrum and hence twice the shift of the lines due to radial velocity is measured, thereby again diminishing the percentage errors of measurement; (3) lines which may not be exactly perpendicular to the length of the spectrum and

[10] Bok and McCuskey, *H.A.* 105 (in press).

which would be difficult to bisect with a micrometer wire are measurable with no loss of accuracy.

In order to determine the radial velocity of each faint star the measures of its spectrum are compared with similar quantities for a bright star having a known radial velocity. Measurement of more than Hγ, Hδ, and NdA does not increase the accuracy of a radial velocity determination sufficiently to warrant the added expenditure of time.

Although the method of measuring radial velocities from objective prism spectra is essentially simple in principle, there are two important considerations which must not be overlooked if the data are to be of value. The first of these is a proper choice of dispersion. The radial velocities needed for galactic studies are those for faint, and hence distant, stars. If the dispersion of the spectra is too large, these will be unobservable but, on the other hand, if the dispersion is reduced too much so as to reach faint objects, the errors of measurement become so large that the data have little value. A compromise must be made, therefore, and for the 16-inch Metcalf telescope with which the present spectra are obtained, an investigation has revealed the results shown in Table I. It is clearly evident from the table that the medium dispersion effects the best compromise. The gain in light by using the spectra shown in Figure 1 over the longest spectra available (46 A/mm at Hγ) is about one magnitude, under comparable conditions of sky and exposure time.

TABLE I

RELATIVE ACCURACY OBTAINABLE FROM SPECTRA OF VARIOUS DISPERSIONS

Dispersion	No. Plates	Average Deviation
High (46 A/mm)	4	10.5 km/sec
Medium (92 A/mm)	5	12.8
Low (230 A/mm)	5	47.6

The entries of Table I represent the mean of the average absolute deviations in kilometers per second of the radial velocity of one image of Vega, centrally located on a plate, relative to two adjacent images of the same star. Obviously the radial velocity so observed is due entirely to errors of observation. The table sufficies to show the accuracy to be expected from radial velocity measures of this type.

The second important correction which must be applied to the radial velocities arises from the fact that the dispersion of the prism varies depending upon the direction in which the light rays pass through it. On the photographic plate, therefore, spectra near the center will be shorter, i.e., have less dispersion, than those near the edges. This results, of course, in spurious radial velocities for those star images well removed from the plate center. Hence it is necessary to apply a correction to all measured spectral lengths in order to reduce them to the corresponding values at the plate center. In many cases the correction amounts to 60 or 70 km/sec for images near the edges of the plate. Experience has indicated the necessity of determining these corrections for each night of

observation. The procedure is to photograph a bright star of known radial velocity in such a way that its images will be distributed uniformly over the plate. Measurement of these spectra yields a curve for each stellar line, giving the correction as a function of the distance from central to non-central image. The corrections are then used for the field plates of faint stars taken on the same night.

General Summary and Conclusions.—As mentioned previously, it has been the aim of the present renewed attack on the radial velocity problem to obtain large quantities of data having an individual accuracy sufficient for statistical investigations. To accomplish this end the accidental dispersion in the velocities must not be greater than the average dispersion of the peculiar motions of the stars themselves. A mean error of ± 15 to ± 20 km/sec is therefore allowable.

In order to maintain the proposed standard of accuracy, the following observational procedure has been found highly essential:

(1) The spectra must be excellent in character. Haze or moonlight during the exposure destroys line quality to such an extent that the measures of such spectra become useless.

(2) At least two multiple image plates for calibrating the change in dispersion over the plate and for establishing the standard dispersion necessary in setting the zero point of the radial velocities must be secured on each night of observation. Usually two different bright stars are used.

(3) At least six field plates, each having a two hour exposure, are necessary to insure the desired accuracy for the fainter stars (M_{ptg} 8.5 to 10.5).

(4) Each plate must be measured in the direct and reversed positions.

With these precautions it has been possible to obtain highly encouraging results from the objective prism plates.

Spectra of thirty-seven stars in the Taurus region yielded radial velocities with an average adopted probable error of ± 5.5 km/sec, while the probable error for a single measurement varied from ± 7.4 to ± 16.0 km/sec, depending upon the quality of the image. The quality of lines in these spectra is excellent. For measurements made on spectra of 163 early type stars in Cygnus, however, an adopted probable error of ± 9.5 km/sec was the rule. The broad hydrogen lines of the A and B stars, of course, precluded a setting accuracy as great as for the narrower lines of the F stars in Taurus.

Nowhere in the investigation thus far has there been found an excess of high velocity stars, as might be expected if the errors made in the measurement of the velocities were large. It must be emphasized that it has not been the purpose of the present work to provide radial velocities which will compete in individual accuracy with those determined by the slit spectrograph. It is essential, however, that the systems agree as a whole, and a comparison of the objective prism velocities with those de-

termined by the slit spectrograph shows this to be sure. Table II gives such a comparison for sixteen stars in Taurus. The radial velocities determined with the slit spectrograph have been taken from Moore's recent catalog.[11] Taurus cluster membership has been assigned according to the work of van Rhijn.[12]

TABLE II

A Comparison of Objective Prism and Slit Spectrograph Radial Velocities

Star	Sp.	m_{ptg}	Obj. Prism V⊙ km/sec	Slit Spect. V⊙ km/sec	Taurus Cluster Member
HD 27397	F0	5.87	+66	+12 to +67	Doubtful
27459	F0	5.55	+36	+29 var	Yes
27628	A3	5.84	+57	+13 to +59	Doubtful
27749	A2	5.74	+18	+36.4 sB	Yes
28034	G0	7.99	+36	+40.9	Yes
28052	A5	4.74	+49	+3 var	Yes
28205	G0	8.6	+45	+40.3	Yes
28294	F0	6.25	+51	+51.5 var	Yes
28355	A5	5.26	+22	+33	No
28485	F0	5.98	+49	+28.8 var	Yes
28527	A5	4.98	+48	+37.7 var	Yes
28546	A5	5.63	+42	+39.2	Yes
28556	F0	5.77	+43	+39.1	No
28568	F0	7.00	+44	+43.1	Yes
28677	F0	6.32	+53	+41 var	Yes
28910	A5	4.89	+41	+3 to +47	Yes

It will, of course, be some time before the complete data bearing on the problem of galactic rotation are available for study. At present, however, detailed results for nearly two hundred stars in Cygnus are in press, and it may be of interest to call attention to one rather striking feature of the velocity dispersion among the B8-A4 stars in this region. Table III exhibits the data in condensed form.

TABLE III

Velocity Dispersion (σ) among the B8-A4 Stars in Cygnus

m_{ptg}	p.e. ±10 km/sec 7.1 - 8.0	8.1 - 9.0	p.e. ±11 to ±13 km/sec 8.1 - 9.0	9.0 - 10.2
Average R. V.	—22.7	—17.3	—22.0	—14.7
No. Stars	16	17	20	41
σ obs. (km/sec)	±15	±16	±22	±32
σ error	±12	±13	±18	±19
σ true	± 9	± 9	±13	±26

For the brighter stars, i.e., $M_{ptg} \leqq 9.0$, the velocity dispersion is quite small, in good accord with the results of other investigators. But for the fainter stars the dispersion is doubled! Whether this effect is real and implies a dynamic change in the velocity characteristics at a distance of four or five hundred parsecs from the sun is hard to say. It may, of course, be an effect of poor correction for accidental error, but this contingency has been checked in other ways from the data at hand, and no change was produced in the result.

[11] *Lick Publ.* 18, 1932.

[12] *Groningen Publ.* 35, 1924.

The method of measurement outlined in the preceding pages is quite economical of time. Approximately twenty hours at the telescope suffice to obtain the complete observational material for any given region, which may contain upwards of two hundred stars. The average time required to measure an image in direct and reversed positions is about eight minutes. A fair estimate of the total time of observation, measurement, and reduction is one and one-half hours per adopted velocity.

It seems quite possible by this method for two observers to actually measure and reduce one thousand radial velocities per year for stars as faint as the tenth magnitude with a moderate amount of telescopic equipment and a minimum expenditure of telescope time. It may be that in a few years those working on the radial velocity problem with slit spectrographs will confine their attention to studying minute shifts due to peculiarities of individual stars, while the investigators of statistical problems will rely on the rapidly accumulating objective prism velocities. There seems to be little doubt of the adequacy of this mass production method for yielding results of high statistical value, at least as far as the present dynamical theories demand.

Miss Cherry's[13] measurements of spectra taken with the 13-inch Boyden refractor at Bloemfontein, indicate an order of accuracy similar to that obtained with the 16-inch Metcalf at Oak Ridge. It thus is possible to use the present methods for studies involving regions of the southern hemisphere as well as the northern. The resulting homogeneity should go far toward permitting a more complete analysis of the many dynamical problems now awaiting the determination of radial velocities for large numbers of faint stars.

Warner and Swasey Observatory
Case School of Applied Science
May, 1937.

[13] *H. A.* 105 (in press).

AT THE PLANETARIUM

What splendid things may human minds evolve,
Through space and time imagination fly . . .
I, spellbound, watched beneath the August sky
The universe, in miniature, revolve,

A symphony of movement and design,
Like rhythmic heartbeat of the unseen One,
Illumined, calm, dependable, divine,
Yet orbit bound, eternally in motion.

In that brief hour the world was pure and sweet
As at creation's dawn, the mind of man
Attuned once more to feel the measured beat
Of life's perfection, one with it again.

—Lisa Odland.

The Known Asteroid Orbits

By ROY K. MARSHALL

The appearance of the 1937 volume of *Kleine Planeten*,[1] containing the elements of the orbits of 1380 asteroids, gives an opportunity to examine the most recent data concerning these numerous and interesting little objects.

The entire history of the asteroids has been quite romantic. The search for a hypothetical planet, with an orbit beyond that of Mars and inside that of Jupiter, was based, it will be remembered, on a fallacious "law" of nature. Referring to the pertinent article in *A Source Book in Astronomy*,[2] we find that the first mention of this curious empirical "law" appears as a note by John Daniel Titius, of Wittenberg, in his translation of Bonnet's *Observations Concerning Nature* (second edition, 1772); Titius is said to have suggested the "law" six years earlier, however. It is most often associated with the name of John Elert Bode, who gave it wide circulation.

The values of the distances of the planets from the sun were supposedly "predicted" by adding 4 to each of the numbers 0, 3, 6, 12, 24, 48, 96 (and, by 1800, a number 192); when these values are divided by 10, the following series of values is obtained, below each of which is placed the best modern value of the actual observed distance.

0.4	0.7	1.0	1.6	2.8	5.2	10.0	19.6	38.8
0.39	0.72	1.00	1.52	...	5.20	9.54	19.19	30.07

At the end of the series are the "predicted" and the actual mean distances for the planet beyond Uranus—we know it today as Neptune. It will be obvious that the law fails utterly to account for Neptune, but it is interesting to note that Pluto's semi-major axis, 39.5, is more nearly "predicted" than is Neptune's. So the "law" predicts a planet which does not appear to exist, and fails to predict Neptune, which certainly does exist, although it was unknown, of course, to Bode.

It has been told many times how an association of observers was formed to look for the planet predicted to have a semi-major axis equal to 2.8 times the distance of the earth from the sun, and how Joseph Piazzi, at Palermo, who was not a member of the association, succeeded in finding it, and later named it Ceres. In a letter addressed to Bode on March 20, 1801, Piazzi[2] says that he found "a comet . . . very small and equivalent to a star of the eighth magnitude," on January 1, and observed it until February 11; during that period it had covered only 3 degrees of its path.

There was a young mathematician, Carl Friedrich Gauss,[3] who had devised a method for determining the elements of the orbit of a body moving in accordance with the law of gravitation: only three observations were required, and the body in question need not have covered a

very long arc of its path. He applied his method to the determination of the orbit and the future positions of the new body discovered by Piazzi, for it had become lost due to bad weather and the illness of the discoverer. It was found on December 31, 1801, just 364 days after its discovery, and soon was recognized, not as a comet, but as a new planet, although a disappointingly small and faint one.

The search for other bodies was continued, and three more, later named Pallas, Juno, and Vesta, were found by 1807; a fifth one, Astraea, was discovered in 1845. Since 1847, at least one asteroid has been found each year. Unfortunately, it is never possible to say exactly how many are known, for images of scores of them have been found on photographic plates made for other purposes (for example, the search for Pluto, and the study of galaxies), and are awaiting measurement. Too, many have been lost (six have not been seen since 1900), and some now being studied may turn out to be these old ones. As soon as a definitely new orbit is computed, the asteroid possessing that orbit is assigned a permanent number (and usually named, by the discoverer), and added to a list published annually by the Astronomisches Rechen-Institut, under the title *Kleine Planeten*. The latest issue of this compilation, published October 1, 1936, contains the orbits of 1380 asteroids; the number of asteroids actually known far exceeds this, however.

The Semi-Major Axes.

From time to time, interesting relations have been found between the elements of the orbits of certain of these bodies and other statistical quantities. Daniel Kirkwood,[4] in a paper before the Buffalo meeting of the American Association for the Advancement of Science, in 1866, pointed out the interesting fact that there were gaps in the asteroid belt, and discussed the connections between the motion of the planet Jupiter and the asteroids which failed to occupy these gaps. Only 88 asteroids were known at this time; ten years later, when the number had almost doubled (total then 169), he rediscussed this feature. The appearance was that asteroids avoided orbits whose semi-major axes were such that the periods would be ½, ¼, and other small fractions of the period of Jupiter.

The first topic of the present paper is an examination of the present status of the "Kirkwood gaps" in the asteroid belt. *Kleine Planeten* lists both the semi-major axis and the mean daily motion for each asteroid. To discuss the relationship between the periods of the asteroids and that of Jupiter it is perhaps more convenient to employ the mean daily motions, but to reduce it to a more graphic form the mean distances (semi-major axes) will be used. It is necessary to refer to Kepler's third law of planetary motions, in which it is stated that the squares of the periods of revolution of any two planets are in the same ratio as the cubes of their mean distances from the sun. Furthermore, for extreme accuracy we should use Newton's modification of this "Harmonic

Law," which is of the form

$$a_1 = a_2 [(P_1/P_2)^2 (M+m_1/M+m_2)]^{1/3},$$

in which a_1, P_1, and m_1 are the semi-major axis, period, and mass of one planet, and a_2, P_2, and m_2 are the same quantities for a second planet; M is the mass of the sun.

Assuming a mass (in terms of the earth) of 330,430 for the sun, 317 for Jupiter, and 0 for the asteroids (the largest one can hardly be more than 0.00025 as massive as the earth), and 5.2028 astronomical units for the mean distance of Jupiter from the sun, we obtain the relation

$$a = 5.2011 (p/P)^{2/3},$$

in which a is the mean distance of an asteroid from the sun when its period is the fraction p/P of the period of Jupiter. In the following table, there are shown values of a corresponding to various values of p/P.

p/P	a	p/P	a	p/P	a
1/4	2.0641	3/8	2.7047	3/5	3.7000
3/10	2.3308	2/5	2.8236	2/3	3.9692
1/3	2.5004	3/7	2.9565	3/4	4.2934
		1/2	3.2765	1/1	5.2011

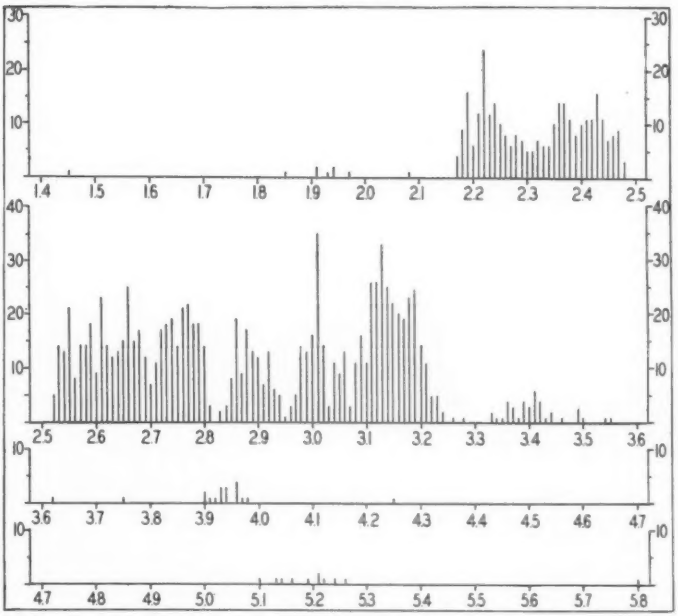

FIGURE 1

DISTRIBUTION OF MEAN DISTANCES FROM SUN FOR 1380 ASTEROIDS

In Figure 1 is shown the distribution of the semi-major axes of the orbits of the 1380 asteroids. The values of a are shown along the hori-

zontal axis, and the numbers of asteroids for each distance are shown vertically. At $a = 1.45$, for example, there is shown only one asteroid (Eros), the semi-major axis of the orbit of which is actually 1.4579. The proper statistical procedure would be to place the vertical line at the center of the interval, but the practice adopted makes it easier to read the diagram.

The most casual inspection reveals that there are gaps at distances corresponding to p/P equal to 1/3, 2/5, and 1/2. A noticeable minimum appears where the value of p/P is 3/8 and 3/7; where p/P is 1/4 and 3/5, the number of known asteroids is so small that no definite conclusion can be drawn, but perhaps it may be granted that there is a strong probability that minima do exist at those points. For p/P equal to 2/3, there is a definite clustering or condensation, as has been pointed out by Russell, Dugan, and Stewart;[5] for p/P equal to 3/4, however, the presence of one asteroid (279 Thule), with a semi-major axis of 4.2585, hardly supports the statement sometimes seen[5] that a condensation occurs there, also. The scattered group near $a = 5.2$ astronomical units constitutes the "Trojan" family, the members of which fulfil one of the more or less exact solutions of the three-body problem, by revolving about the sun with approximately the same period as Jupiter, and about the same distance from Jupiter as separates them from the sun. This, it will be remembered, is sometimes called the equilateral solution, because (in this example) Jupiter, the Trojan asteroid, and the sun are at the vertices of an equilateral triangle. To be sure, the asteroid does not occupy this position constantly; it oscillates for small distances in one direction or another from the mean position, as though there were at the precise point a "dynamic whirlpool" from which the asteroid tries in vain to escape.

A closer examination of the gaps and concentrations, in the order set down in the preceding paragraph, may be of interest.

$p/P = 1/3$; $a = 2.5004$

Asteroids with mean distances equal to approximately 2.5 astronomical units are sometimes said to be of Hestia type; Hestia is asteroid number 46, discovered in 1857 by Pogson; its mean distance from the sun is 2.5259 astronomical units. There are nine asteroids between 2.4701 and 2.4794; then there are three asteroids (numbers 1257, 495, and 877) between 2.4859 and 2.4874. The next one (619 Triberga) has $a = 2.5203$; there are four others between 2.5213 and 2.5288, and fourteen between 2.5302 and 2.5397. For the twelve asteroids inside the gap, the average is one asteroid per 0.00157 astronomical unit; there is then a gap of 0.0329 astronomical unit, then one asteroid per 0.00108 unit. To examine a wider range, we find that the average rate from 2.17 to 2.48 is one asteroid per 0.0010 unit; from 2.52 to 2.82 the average is one per 0.0007 unit. It is obvious that the regions adjacent to the gap are slightly less crowded than the regions farther from the gap.

$p/P = 2/5$; $a = 2.8236$

Between 2.8004 and 2.8159 there are seventeen asteroids (the last two being 541 Deborah and 673 Edda); there follows a clear gap of 0.0171 unit, to 975 Perseverantia, at $a = 2.8330$; there are only four others out to 2.8491.

$$p/P = 1/2;\ a = 3.2765$$

The asteroids in this neighborhood are sometimes said to belong to the Hecuba (number 108, discovered by R. Luther, 1869) group; this asteroid has $a = 3.2088$. Between 3.2017 and 3.2457 there are thirty-seven asteroids; another (1101 Clematis) has $a = 3.2621$; then occurs a gap of 0.0223 unit to $a = 3.2844$, where is found number 1362; 401 Ottilia is at 3.3319, then there are three others at less than $a = 3.3560$.

$$p/P = 3/8;\ a = 2.7047$$

The pronounced minimum at the value of a for which $p/P = 3/8$ is certainly real, and, if the perturbations of Jupiter are responsible for it, there would seem to be a strong likelihood that asteroid 868 Lova, with $a = 2.7042$, will suffer considerable changes of orbit, since its distance is almost precisely equal to the critical value. Its opposition is scheduled for December 12, 1937. In this region, from 2.6800 to 2.7042, the thirty-four asteroids are spaced at an average of 0.00073 unit per asteroid; there is a gap of 0.0041 unit; then thirty asteroids are spaced at an average of one per 0.00073, between 2.7083 and 2.7300. In spite of these precisely identical average figures, there seems to be a tendency here, as at some other gaps and minima, for asteroids to crowd up close to the inner limit of the gap and slightly to avoid the outer edge of the gap.

$$p/P = 3/7;\ a = 2.9565$$

Asteroid 677 Aaltje, with $a = 2.9537$, lies closest to this gap; there are eleven between 2.9318 and 2.9455; outside the gap, there are eight asteroids between 2.9641 and 2.9992. The average separation for the dozen inside the gap is 0.00199 unit; outside, the average separation is 0.00439 unit, in spite of the fact that the innermost one is 0.0079 unit beyond the critical distance; this relatively open space and wider separation again leads to the suspicion that the asteroids in the neighborhood prefer the inner border of the gap.

$$p/P = 1/4;\ a = 2.0641$$

The single asteroid with a semi-major axis between 2.00 and 2.10 is 330 Adalberta, whose orbit is somewhat uncertain (the eccentricity being unknown); the asteroid has not been seen since 1892. The accepted value of a for this body is 2.0893 units. Inside the gap, the seven asteroids are 1355 (for which $a = 1.8519$), 1235 Schorria, 1019, 1221 Amor, 1103, 434 Hungaria, 1139, and 1025 Riema (with $a = 1.9788$).

In passing, it may be mentioned again that the solitary asteroid represented with $a = 1.4579$ is 433 Eros.

$$p/P = 3/5;\ a = 3.7000$$

The two asteroids in this neighborhood are 522 Helga, at 3.6230, and

1144 Oda, at 3.7506.

$$p/P = 2/3;\ a = 3.9692$$

There are sixteen asteroids between 3.9033 and 3.9805; the mean value is 3.9438. Of these, fourteen lie inside the critical distance, the greatest value of a being 3.9676. These sixteen asteroids are, in order of increasing distance, 334 Chicago, 1256, 1202 Marina, 1038 Tuckia, 958 Asplinda, 1268 Lydia, 361 Bononia, 190 Ismene, 748 Simeïsa, 499 Venusia, 153 Hilda, 1345, 1180 Rita, 1162 Larissa, 1212 Francette, and 1269.

$$p/P = 3/4;\ a = 4.2934$$

It has already been mentioned that 279 Thule is the solitary asteroid in this region; its mean distance is 4.2585 units.

$$p/P = 1/1;\ a = 5.2011$$

The Trojan asteroids represented here are 1173 Anchises, 911 Agamemnon, 624 Hektor, 1143 Odysseus, 617 Patroclus, 659 Nestor, 1172 Aeneas, 588 Achilles, 884 Priamus, and 1208 Troilus, in order of increasing value of semi-major axis. The values of a range from 5.1037 to 5.2608. It is interesting that the mean of the ten represented is 5.1908, which, in spite of the relatively close grouping of the ten, is not very close to the critical value. When we consider some of the other elements of the orbits of the Trojans, we find some interesting things. The mean of the values of the eccentricity for these orbits is 0.1008, as compared with a general mean for all known orbits equal to 0.1484. The mean value of the inclination of these Trojan orbits to the ecliptic, however, is 14°.643, as compared with the general mean of 9°.667. Moreover, these eccentricities are curiously distributed. For the first five of the group, in the order of increasing value of i, the values are (approximately) 3, 5, 7, 9, and 10 degrees; for the next four, the values are 17, 18, 22, and 22 degrees. The asteroid with the highest inclination (33°.619) is Troilus, which has the largest semi-major axis. This seems to be a distinct division into three groups, on the basis of the value of the angle i.

The asteroid with the largest orbit represented is 944 Hidalgo, with a equal to 5.7999 (shown as 5.80). Until recently, this planet held the distinction of possessing the highest values of eccentricity and inclination, but it is believed that the asteroid 1936 CA Adonis has a higher eccentricity, tentatively set at 0.7632, as compared with 0.6528 for Hidalgo. This new asteroid (not yet assigned a permanent number) was discovered by Delporte on February 12, 1936, five days after it had come closer to the earth than any other body except the moon and meteoric bodies; its distance at that time is believed to have been only 1,209,000 miles. The asteroid has an orbit inclined only 1°.417 to the plane of the ecliptic, and the mean distance from the sun is 1.8644, which helps to fill up the gap between asteroid 1355, at 1.8519, and 1235 Schorria, at 1.9103.

The Inclinations of the Orbits.

As was mentioned earlier, the general mean for the inclinations of the asteroid orbits to the plane of the ecliptic is 9°.667. Only 1379 orbits are considered here, and in the following sections; asteroid 330 Adalberta is omitted, because of the uncertainty of its orbit. In Figure 2 is a correlation table with the angle i as one of the coördinates. The horizontal coördinate is the angle ϕ, which is used in *Kleine Planeten* (and many times in computations) as a measure of the eccentricity of the orbit. The relation connecting the two quantities is the simple one that $e = \sin \phi$. The construction and use of such a table is simple; for ex-

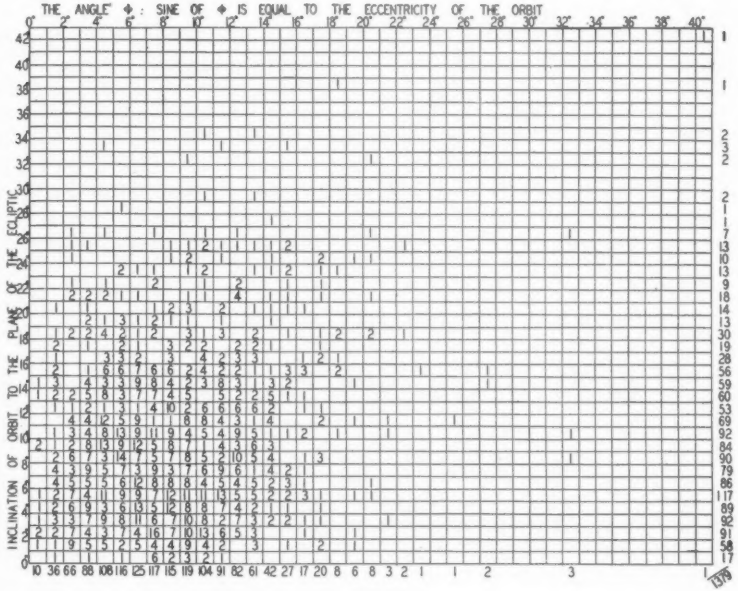

Figure 2

Distribution of the Eccentricities and Inclinations for 1379 Asteroids

ample, the number 7 in the square which is bounded by the lines $i = 3°$ and $i = 4°$ and $\phi = 3°$ and $\phi = 4°$ means that there are 7 asteroid orbits whose values of i and ϕ are included within these limits. The numbers at the bottom of the table are the totals of the columns; the numbers at the right edge are the totals of the rows; these totals should add up to 1379, the grand total of the number of asteroid orbits considered in the table.

A quick inspection suffices to show that there are relatively few values of i greater than 25°. As a matter of fact, there are but 33 examples. The mean value of ϕ for these is 13°.013, giving some support to the

common statement that high inclinations are generally accompanied by high eccentricities.

Three of these high inclinations belong to asteroids whose mean distances from the sun are between 1.90 and 2.00, where we have seen a condensation to exist. There are four of them between 2.30 and 2.45; there are eight between 2.57 and 2.70; there are six between 2.74 and 2.80; the next eight lie between 2.92 and 3.22; two are at 3.37 and 3.42; one is a Trojan, at 5.2608 (1208 Troilus); the last is 944 Hidalgo, with $a = 5.7999$. It is tempting to speculate on the connection between the high inclinations and the critical values of a; intuitively, one might suspect a connection, but the dynamical details of the many problems involved have never been treated.

The Eccentricities.

There are twenty-one values of the angle ϕ greater than 20°; this means that there are that number of asteroids with orbits of eccentricity greater than 0.34. For only a few of these is the connection between high inclinations and eccentricities obvious, but again we find something interesting when we consider the distribution of these high values of ϕ. One value belongs to an asteroid with mean distance 1.9239; two are close together at 2.3927 and 2.3997; the next is at 2.5274; three are fairly closely grouped at 2.5838, 2.5852, and 2.5911; there are two at 2.6123 and 2.6175; the next three are at 2.6269, 2.6288, and 2.6289, and there is one not far beyond at 2.6324; from this point on, they are fairly widely separated, at 2.6640, 2.6844, 2.7276, 2.7904, 2.9998, 3.1333, 3.3398, and 5.7999. There seems to be no relation between the values of a and the values of ϕ, however; the highest values of ϕ are scattered at random through this range of a.

In spite of the fact that a considerable number of asteroids have mean distances between 2.17 and 2.30, there are no very large values of ϕ among them. Similarly, between a equal to 2.96 and 3.24, there are a great number of asteroids, but only two have extremely large values of ϕ. Nine of the high values lie between the mean distances of 2.5838 and 2.6324. It will be remembered that there were eight high values of the orbital inclination included between approximately the same limits. Only three of the asteroids with high values of i have, however, high values of ϕ, and only one of these (1036 Ganymede) has a very high value of ϕ (32°.682). It seems that there is some force acting upon the asteroids in this neighborhood to force them to have either high inclinations or high eccentricities. Such a conclusion may be unjustifiable; certainly when we include slightly smaller values of ϕ and i the conspicuous condensations vanish, and the distribution of high values of i and ϕ resembles the distribution of all asteroids, with respect to a.

The Relation Between i and e

As noted before, Figure 2 does not display in a very obvious manner the truth of the relation so often stated for the eccentricities and inclina-

tions of the asteroid orbits. The relation can be seen, however, when means are taken. For example, the mean value of i and the mean value of ϕ may be taken for all asteroids for which i lies between 0° and 1°; this mean ϕ may be converted into a mean e by taking the sine of ϕ. Of course, this will not be precisely equal to the mean e which would be obtained by taking the sines of the individual values of ϕ, which are then meaned, but it will not differ from this proper value by an excessive amount. Similarly, means may be taken for i and ϕ for each 1-degree interval of i, and the results are shown in the following table.

Mean i	Mean ϕ	Sine of mean ϕ	Mean i	Mean ϕ	Sine of mean ϕ
0°.634	7°.867	0.13687	18°.501	9°.922	0.17231
1.523	7.451	.12968	19.470	7.175	.12490
2.480	8.082	.14059	20.548	10.042	.17437
3.519	8.056	.14004	21.496	9.611	.16696
4.500	7.726	.13444	22.539	9.983	.17336
5.501	7.655	.13321	23.453	11.598	.2011
6.464	8.138	.14156	24.606	13.235	.2289
7.519	8.154	.14183	25.250	11.544	.2002
8.474	8.582	.14923	26.483	12.766	.2209
9.498	7.167	.12476	27.777	14.811	.2556
10.494	8.799	.15297	28.758	5.504	.0959
11.465	8.596	.14947	29.558	11.972	.2074
12.515	9.948	.17276	32.744	14.936	.2577
13.428	7.835	.13632	33.841	10.559	.1833
14.506	8.773	.15252	34.642	12.268	.2124
15.492	9.446	.16412	38.879	18.678	.3202
16.442	10.093	.17525	42.542	40.973	.6557
17.566	9.050	.15730			

When these values are plotted together (that is, mean i against sine of mean ϕ), the resulting curve resembles an exponential curve, except that it is too concave upward. That is easily seen when the mean i is plotted against the logarithm of the sine of mean ϕ; the resulting line is still slightly concave upward.

While it would doubtless be possible to find a strict relation between i and e, perhaps of the form of some modification of the exponential function, the weights of the mean values beyond $i = 23°$ were considered to be too low to warrant an effort of this kind. As a passable approximation for the large majority of orbits (1326 of the total 1379), for which i is included between 0° and 23°, there has been derived the relation

$$e = (1.42 + 0.02\,i)/11,$$

which is seen to be a straight line. When values of e are computed by means of this formula, the summation of the residuals (in the sense observed minus computed) is —0.0057; the mean O—C is 0.0083 (taken without regard to sign); the mean $(O—C)^2$ is 0.00015. These residuals show that it would probably be of little profit to seek a better relation for the first 23 entries of the foregoing table. The departure from a straight line is, however, quite obvious and definite, when the values are plotted; furthermore, the higher values (beyond those used in deriving the relation given) join the earlier ones smoothly, so that a single

relation expressing all of them should be derivable, if one wishes to consider the higher values sufficiently well established.

The exceptional orbits have been discussed so often that little concerning them will be set down here, except their names. They are 944 Hidalgo, 887 Alinda, 1221 Amor, 719 Albert, 1036 Ganymede, and the new discoveries Apollo (discovered by Reinmuth in 1932) and Adonis (Delporte, in 1936). These are notable because of high values of i or ϕ (or both), and close approaches to the earth. The best present orbit for 1932 HA Apollo (with $a = 1.4445$) shows it to be so eccentric that at perihelion the asteroid is more than six million miles inside the orbit of Venus, while at aphelion it is more than sixty-five million miles beyond the orbit of Mars! This orbit indicates that in May, 1915, the little body, perhaps no more than a mile or two in diameter, was only a little more than 1,800,000 miles from the earth. As has been mentioned earlier, 1936 CA Adonis (with the highest known eccentricity) holds the record for close approaches, with the value of 1,209,000 miles. At perihelion, this asteroid is but 44,000,000 miles from the sun, or only about 7,000,000 miles outside the orbit of Mercury; at aphelion, it is almost seven times as far away as at perihelion, or more than 160 millions of miles beyond the orbit of Mars. Its low orbital inclination (only 1°.417) has led to some fear lest it should sometime encounter the earth, or perhaps Mars or Venus. That it has not already done so is a good reason for believing either that it never will or that it will soon! When this body has been observed at another apparition, its orbit will probably become better known; investigations at that time may indicate definitely that we are safe from the possibility of collision with it.

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[1] Ferd. Dümmlers Verlagsbuchhandlung, Berlin (1936).
[2] Shapley and Howarth, McGraw-Hill Book Co. (1929), p. 180.
[3] *Source Book*, p. 183.
[4] *Source Book*, p. 305.
[5] *Astronomy*, Ginn and Co. (1926).

NOTE ADDED DECEMBER 20, 1937: The arrival, a few days ago, of *Kleine Planeten* for 1938, permits inclusion of any important material which has been added since the above article was prepared. The number of orbits now accepted is 1417, including a new Trojan, 1404 Ajax, with $a = 5.1344$, $i = 18°.160$, and $\phi = 6°.434$.

The inclusion of these 37 new orbits changes the mean value of i from 9°.667 to 9°.633, and the mean value of e from 0.1484 to 0.1482.

The asteroids Apollo and Adonis have not yet been assigned permanent numbers. Added to these, but not yet included in *Kleine Planeten*, is the new Reinmuth object, which appears to have been considerably less than a million miles from the earth at the end of October, 1937.

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Nicolas Reymers and the Fourth System of the World

By GRANT McCOLLEY

For a number of decades there has existed a noticeable tendency to regard the important era from 1575 to 1700 as one wherein two astronomical systems, the Ptolemaic and the Copernican, stood as rivals before Europe.[1] Few presumably accurate generalizations could be more misleading. Throughout the period the chief rival of the Copernican theory was not the Ptolemaic, but rather a third hypothesis, the Tychonic. As J. L. E. Dreyer succinctly observed, "about the year 1630, nobody, whose opinion was worth anything, preferred the Ptolemaic to the Tychonic system."[2] Indeed, so far as continental Europe was concerned, the geo-heliocentric hypothesis, whether Tychonic or modified Tychonic, was known and employed more widely than the Copernican.[3] Nor was the geo-heliocentric the only additional conception to be advanced during this era of change and unrest in cosmological thought, for the air was charged with variant hypotheses. Many theories were vigorously advanced, and Robert Burton well described the ferment and tumult of his age when he wrote:[4]

> Fracastorius will have the earth stand still, as before; and to avoid that supposition of eccentrics and epicycles, he hath coined seventy-two homocentrics, to solve all appearances. Nicholas Ramerus [Reymers] will have the earth the center of the world, but movable, and the eighth sphere immovable, the five other planets to move about the sun, the sun and moon about the earth. . . . Roeslin censures all, and Ptolemeus himself as insufficient. . . In his own hypothesis he makes the earth as before the universal centre, the sun to the five upper planets, to the eighth sphere he ascribes diurnal motion, eccentrics and epicycles to the seven planets, which had been formerly exploded . . . as a tinker stops one hole and makes two. In the meantime, they hoist the earth up and down like a ball, make it stand and go at their pleasure—one saith the sun stands, another he moves; a third comes in, taking them all at rebound, and . . . finds certain spots and clouds in the sun . . . by means of which the sun must turn upon his own centre, or they about the sun.[5]

All of these systems and their variants led the century away from the long ingrained Ptolemaic cosmology, and by so doing assisted in some measure the advance of astronomy. A number did more than this, and placed their advocates and followers half way between the old and the new. One hypothesis went even further, and brought its friends virtually to the door of heliocentric astronomy. This hypothesis was the "fourth system of the world." According to the main outlines of the system, earth was placed in the center of the fixed stars, or universe,

and produced night and day by rotation on its axis. The sun stood in the center of the orbits of the remaining planets, and moved annually about the earth, carrying with it, as on epicycles, Mercury and Venus. The superior planets encompassed both sun and earth with a single orbital revolution, made about the central sun. Suspension of planetary

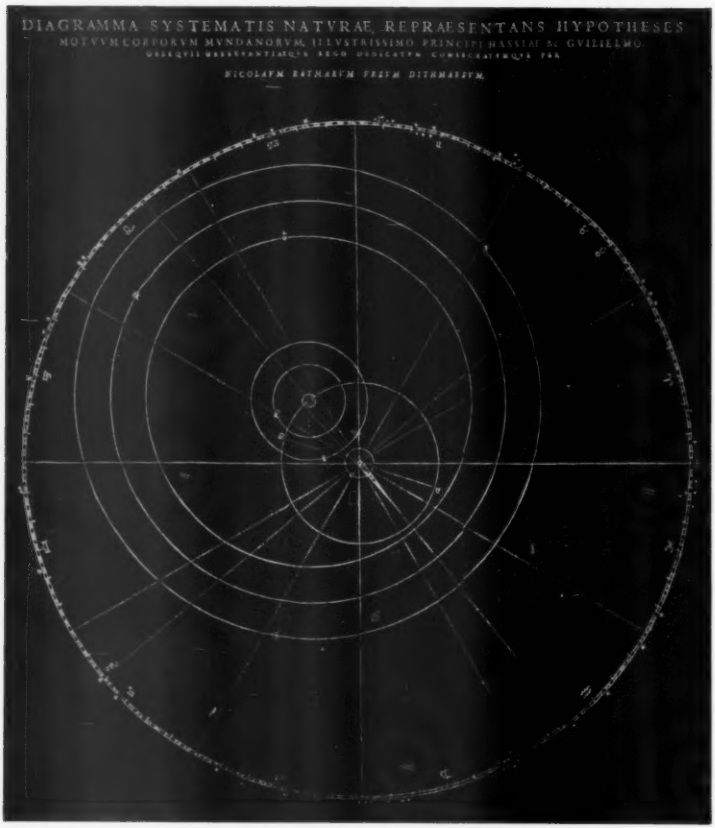

FIGURE 1
REDUCED FACSIMILE OF FINAL PAGE OF NICOLAS REYMERS' *Fvndamentvm Astronomicvm*, ARGENTORATI, 1588.
(Reproduced by courtesy of the John Crerar Library from photostatic copy of the original at the Royal Library of Copenhagen. Length of top line in photostat, 241 mm.)

motion at a given time produced the order of Copernicus: Sun, Mercury, Venus, Earth, Mars, etc., and, with the exception that the annual revolution was performed by the sun rather than by the earth, the sys-

tem was in its major details quite similar to the heliocentric hypothesis.

In a fragmentary form, this system of the world had appeared as early as Heraclides of Pontus, who believed not only in the diurnal rotation of the earth, but that Mercury and Venus revolved about the sun.[6] In the fourteenth century of our era, the first of these two important ear-marks of the hypothesis was advocated by Nicolas Oresme, and the second accepted by him as "reasonable."[7] By 1586 the theory was formulated as an astronomical system by Nicolas Reymers, and during this year was set up in model form for the Landgrave at Cassel.[8] Two years later Reymers presented it in detail in his *Fvndamentvm Astronomicvm,* and a fourth system of the world entered the arena.[9]

The attraction of the fourth system of the world to able scientists of the late sixteenth and early seventeenth centuries is well illustrated by the inability of William Gilbert to choose between this hypothesis and the Copernican theory. Superficially, his choice appears to waver between the Copernican and the geo-heliocentric conceptions, but since he firmly believed in the diurnal rotation of the earth, his actual choice lay between the heliocentric and the fourth system of the world—a combination of the theory of the earth's diurnal rotation and the geo-heliocentric hypothesis.[10] In 1609, David Origanus (Tost) sponsored the combination system in his *Ephemerides,* and four years later it was advocated by the well-known Englishman, Marke Ridley.[11] In 1622 the system was utilized by a former assistant of Tycho Brahe, Christian Longomontanus (Longberg), in his frequently reprinted and generally respected *Astronomia Danica.*[12] With a variation in the position ascribed to the earth, and in incidental detail, the hypothesis was advanced in 1644 and 1653 by Andrea Argolus, and before 1672 by Michael Havemann.[13] The extent to which Reymers influenced Ridley, Origanus, Longomontanus, and others to adopt and advocate his combination of the geo-heliocentric hypothesis and the theory of the diurnal rotation of the central earth quite naturally cannot be determined, but it may be said that he was the first of the moderns to employ such a combination system, and that it was available in two works, the *Fvndamentvm* of 1588 and *De Astronomicis Hypothesibvs* of 1597. Because of his bitter dispute with Tycho, his work would have been known to Longomontanus, and probably to Origanus and Ridley.[14]

The Fourth System of the world was not, however, the only contribution to cosmological thought which Reymers made in the *Fvndamentvm.* He proved himself, as Dreyer has remarked, an able mathematician, and, in addition, presented conceptions of the universe far in advance of those held by a great majority of his contemporaries. It was with good reason that in his letter of 15 November 1595, Kepler addressed himself to Reymers as "Tuae discipulus."[15] These advanced conceptions of the cosmos are presented in chapter V of the *Fvndamentvm* as astronomical theses, and are described by the author as an integral part of his new hypothesis.

The first of the several theses enunciates a fundamental principle of scientific cosmology, one which, so far as the present writer has observed, was not stated by any modern astronomer prior to Reymers. In brief, it is that the universe is a self-existent physical entity: "I. Mundus est systema rerum naturalium per se existentium."[16] A second important thesis is that the closer the air is to earth, the heavier and denser it is, and, conversely, the farther removed, the lighter and more tenuous: "III. Aër est Essentia tenuissima & subtilissima: eaque quo a terreno globo remotior vel sublimior . . . tenuior ac subtilior: contraque quo terrae propinquior seu himilior . . . crassior ac densior existit.[17] A third significant thesis, one which implicitly rejects the notion of a sphere of fire, is that the air extends far beyond the fixed stars, and that the fixed stars themselves exist either scattered through infinite space or that they are dispersed with one far beyond another: "V. Credibile tamen est & minime absurdum, imo ipsi rationi ac naturae consentaneum, longe ultra stellas fixas aërem extensum atque expansum fore: ideoque & ipsas stellas fixas tanquam Cyclades, per aut infinitum aut longe alterius extensum aëra sparsas, existere."[18]

In two further theses Reymers states positively that there is some force which holds together in their proper places the bodies of the universe, and, quite as positively, that he does not know what this force is: "XVI. Corpora denique Mundana immobilia sunt, quae in eodem semper loco persistunt, seu eidem loco fixa inhaërent . . . XVII. Tota autem fixarum stellarum nescio quo vinculo cohaerens atque coagmentata connexio seu compraehensio . . . Aplane."[19] It also was the belief of Reymers that, as Scripture says, the stars are infinite in number: "XVII . . . earumque denique numerum, sarcis [*sic*] literis id testantibus, omnino esse infinitum, infinitamque multitudinem."[20] We also find in Reymers an anticipation of a theme which grew increasingly important during the seventeenth and the early eighteenth century, the conception that in comparison with the vast and indefinite, or infinite universe of the new astronomy, man was not only small, but insignificant and despicable: "pusilla nos atque misellula animalcula, homines dicta."[21]

More pleasant to contemplate is the effective analysis of Astronomy as resting upon the two pillars of mathematical calculation and observation:

Methodica est, quae tractat Methodum Calculandi & Observandi: dictarum videlicet duarum Astronomiae partium.

Astronomiae partes sunt
- Calculatio, eaque in
  - Logistica computatione
  - Rebus Meretricis
    - Extructio Canonis sinuum
    - Doctrina Triangulorum
- Obseruatio, eaque est
  - Locorum stellarum fixarum
  - Motuum planetarum ac terrae[22]

It is of further interest that in the diagram of his system which follows folio 40 of the *Fvndamentvm*, Reymers not only depicts a number of stars as located in space at varying distances from the earth, but groups these stars in constellations, and omits entirely both the concavity and convexity of the eighth sphere. In the diagram presented in *De Revolutionibus,* Copernicus omitted the bounding convexity of the sphere, but employed the interior concavity and depicted no stars whatsoever.[23] Some decades later, Thomas Digges illustrated his partial digest and translation from Copernicus by a diagram which omitted the bounding convexity, and, in addition, depicted the fixed stars as dispersed in space.[24] However, following Copernicus, Digges retained the interior concavity of the eighth sphere, and made no attempt to group the fixed stars in constellations. Rather, he scattered them indiscriminately at regular intervals beyond the concavity. Until some similar and earlier diagram is found, it may be said that Reymers was the first to publish a diagram which included neither the concavity nor the convexity of the eighth sphere, which depicted stars as dispersed in space at varying distances from the earth, and made some attempt to group these stars in constellations.

Without pausing to review the evidence presented in this note, it may be said, I believe, that the Fourth System of the world has some place in the history of the rise of the new astronomy, that Nicolas Reymers should be recognized as the first modern to use and the first astronomer to present in organized form this Fourth System, and that in addition he made other important and vital contributions to the progress of human thought, both in the realm of astronomy and in what may be termed the domain of cosmic philosophy.

References

1. Such an interpretation, although not unknown in scientific works, is most common in general and special histories. In his *History of Modern Europe* (1924, I, 197-8) Professor Carlton Hayes describes the Ptolemaic theory as having been cherished throughout the Middle Ages, and continues to say, "However, a contradictory theory of the solar system was propounded and upheld in the sixteenth century, quite supplanting the Ptolemaic theory in the course of the seventeenth. The new system is called Copernican." The prevalence of this belief among historians of literature is discussed by the present writer in "The Astronomy of *Paradise Lost*," *Studies in Philology,* XXXIV (1937), 209 ff.

2. *History of the Planetary Systems,* Cambridge, 1906, p. 416.

3. Some evidence of the prestige of the geo-heliocentric system is given by Dreyer, *op. cit.*, chapter XIV, and in his *Tycho Brahe,* Edinburgh, 1890, p. 184 and *passim.* Additional evidence will be found in "The Astronomy of *Paradise Lost*," *loc. cit.*, section IV. It is of interest that the geo-heliocentric hypothesis was expounded in two of the most popular school-books of the seventeenth century, the *Janua Linguarum* and *Orbis Pictus* of Bishop John Amos Comenius. In the edition of London, 1670, of the *Janua Linguarum*—a sixth edition had been reached in 1645, the geo-heliocentric system is diagrammed on plate 2, and discussed pp. 142 ff. In the twelfth London edition of the *Orbit Pictus,* published in 1777, the system is discussed p. 132. As late as 1872 it was seriously advanced by a Commander in the Royal Navy, R. J. Morrison, in *The New Principia; or True System of Astronomy,* London.

4. One of the more prevalent of these hypotheses, with a number of its variant details, is discussed by the present writer in "The Theory of the Diurnal Ro-

tation of the Earth," *Isis*, XXVI (1937), 392-402, and "The Astronomy *of Paradise Lost*," *loc. cit.*, section I.

5. *Anatomy of Melancholy*, "Air Rectified" (London, 1898, p. 328).

6. Because of the multiplicity of doxographic sources regarding the cosmological theories of Heraclides of Pontus, I omit their citation and refer the reader to the fully documented discussion of Sir Thomas Heath, *Aristarchus of Samos*, chapter XVIII, "Heraclides of Pontus."

7. *Traistié du Ciel et du Monde*, Bibliothèque Nationale, fonds français, ms. no. 1083, as quoted by Pierre Duhem, "Un Précurseur Français de Copernic: Nicole Oresme," *Revue Générale des Sciences Pures et Appliqueés*, XX (15 Nov. 1909), 871-872, and *Le Système du Monde*, III, 158.

8. According to a letter from Rothmann to Tycho (*Epist. Astron.*, pp. 128-9), a model of Reymers' system, executed by Bürgi, had been completed for the Landgrave several years before 1588.

9. Chapter V (pp. 37 ff.). The complete title of the book is *Nicolai Raymari Vrsi Dithmarsi, Fvndamentvm Astronomicvm; id est, Nova Doctrina Sinvvm et Triangvlorvm*, Argentoratti . . . 1588. I wish to express my deep appreciation for the unusual courtesy of Dr. F. Christian Bay, Librarian of the John Crerar Library, Chicago, in obtaining from the Royal Library at Copenhagen a photostatic copy of this rare work, and of the even rarer *De Astronomicis Hypothesibvs, sev Systemate Mvndano* . . . Pragae Bohemorvm . . . 1597.

10. My reference is not to *De Magnete*, London, 1600, but to the posthumously published *De Mundo nostro Sublunari, Philosophia Nova*, Amstelodami, 1651, pp. 135, 139 and *passim*.

11. Origanus, *Ephemerides*, Francofurti, 1609, Epistle Dedicatory, and *passim*. Ridley, *A Short Treatise*, London, 1613, pp. 1, 14. The closeness of the fourth system of the world to the heliocentric hypothesis is well illustrated by the fact that it deceived an able student of sixteenth century astronomy, Francis Johnson, and led him to believe that its advocacy by Ridley was an advocacy of Copernican astronomy. The extent of the deception is indicated by Mr. Johnson's unqualified declaration, "Thomas Digges and Modern Astronomy," *Osiris*, I (1936), 407, that "Marke Ridley . . . accepted Gilbert's ideas, but went still farther and was an outright Copernican."

12. I, i, iv (Amsterdami, 1640. pp. 161 ff.).

13. Argolus, *Pandosion Sphaericvm*, caput III (Patavii, 1653, pp. 9 ff.). Havemann, *Astraea sive Siderali Scientia*, as cited by Otto von Guericke, *Experimenta Nova*, Amstelodami, 1672, pp. 19-20. I am indebted to Von Guericke for the term "fourth system of the world," the most important single element of which was, to him, the diurnal rotation of the earth. Von Guericke regards Heraclides of Pontus as the author of the hypothesis, and names among its later followers "Origanus, Longomontanus . . . & alii. One may suspect that the "others" included more than the several advocates listed above. Indeed, it would be possible to include Anton Deusing, *De Vero Systemate Mundi*, Amstelodami, 1643, among the partial supporters of the hypothesis.

14. The appearance in Reymers' *Fvndamentvm* of a system which, the earth's diurnal rotation excluded, was basically similar to that presented about the same time by Tycho in chapter VIII, *De Mundi Aetherei Recentioribus Phaenomenis Liber Secundus*, led the Danish astronomer to accuse Reymers of having stolen the hypothesis from him. The judgment of Dreyer, *Tycho Brahe*, ed. cit., p. 185, is that "the verdict of posterity can only be 'not proved.' In his writings Reymers has shown himself an able mathematician, and there is no reason whatever why he should not independently have arrived at a conclusion similar to the idea which Tycho conceived on the planetary motions." It may and perhaps should be added that the two systems differed fundamentally in that one included the diurnal rotation of the earth, and that Reymers had announced his discovery in 1586, two years before the publication of Tycho's book.

15. Reymers prints this letter in his *De Astronomicis Hypothesibvs*, ed. cit., sig. D, recto and verso. Needless to say, Kepler largely retracted his eulogy when he became Tycho's assistant.

16. Folio 37, recto.

17. *Ibid.*

18. Folio 37, verso. In thesis XVIII, Reymers partially qualifies this conception with the statement that it has not been established and cannot be established by man that the fixed stars are dispersed in the air at varying distances from the earth. He conjectures, however, that the larger stars are the closer; the smaller those more remote: "Confecturam tamen facimus, maiores apparentes terrae esse propinquiores: e contrario vero minores apparentes a terra esse remotiores, longioreque interuallo ab ipsa fore dissitas."

19. Wolio 38, verso.

20. *Ibid.*

21. Folio 40, recto (Diagrammatis Hypothesium Declaratio, IV). It is understood that the comparison of tiny man with the vast universe, or, more frequently, of the point which was the earth and the universe, had been a commonplace for many centuries. However, the conception that man was a petty and wretched animalcule *because* of the incomprehensible vastness of the cosmos, did not, during the Christian era, achieve noticeable importance until the seventeenth and early eighteenth centuries.

22. Ed. cit., folio 1, recto.

23. Book I, chapter X.

24. *A Perfit Description of the Caelestiall Orbes according to the most auncient doctrine of the Pythagoreans, latelye reuiued by Copernicvs,* an appendix to *A Prognostication euerlastinge,* London, 1576, folio 43. Digges apparently was the first astronomer to comment on the fact that the system of Copernicus included an unbounded or infinite eighth sphere. He was independently followed, among others, by Rothmann, Tycho, Kepler, la Galla, and Riccioli. The idea that the fixed stars were dispersed at varying distances from the earth within the eighth sphere was of course a commonplace to many Ptolemists, and during the sixteenth century an appreciable number of works so depicted them. One illustration of this practice will be found in *Christophori Clavii . . . In Sphaeram Ioannis de Sacro Bosco,* Romae, 1585, p. 254.

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Visibility of the Planets for 1938

By WILLIAM MALCOLM BROWNE

The visibility of the planets during the year 1938 is shown by the accompanying diagram. It may be used equally well in any latitude.

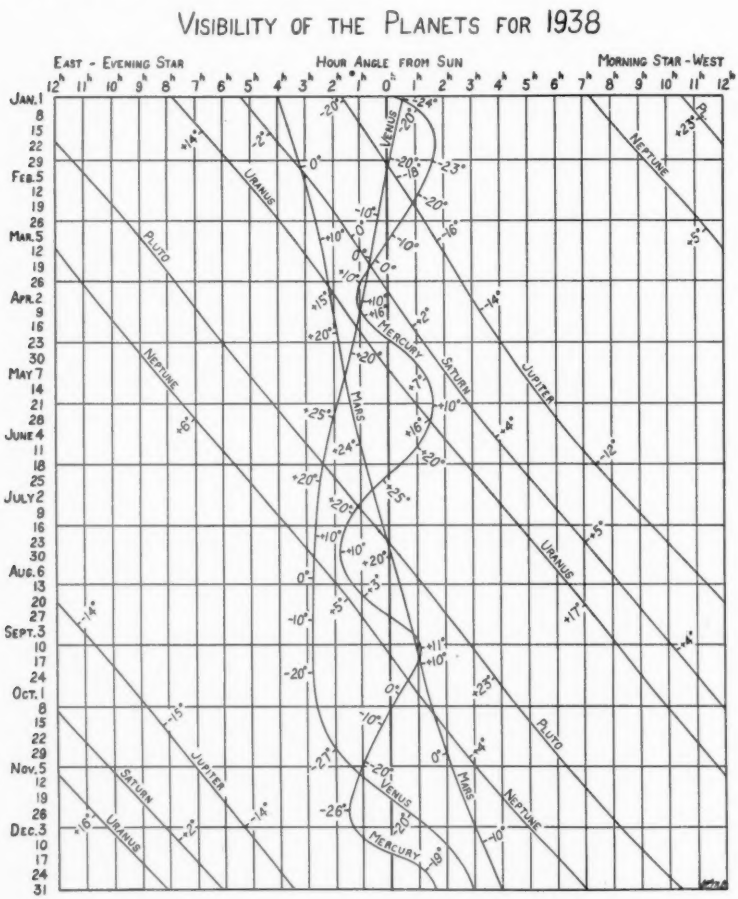
The path of the sun is represented by the heavy vertical line in the center of the diagram marked 0^h. The lines designated by the names of the various planets show how far east or west of the sun the planets are at any particular date. The declination of each planet is indicated at various points along its path, as it also varies throughout the year and should be considered in determining the visibility of a planet.

A particular planet may be seen at some time of night during any part of the year except when the planet is too close to the sun. When a planet is less than about an hour from the sun, it is generally too close to be visible. In general, the farther a planet is from the sun, the easier it will be to see. Also the planet will be visible for a longer portion of the night.

Since the sun is on the meridian, or reaches its maximum altitude, at about noon, a planet will be on the meridian, or reach its maximum

altitude, as many hours before noon as the planet is west of the sun, or as many hours after noon as the planet is east of the sun.

When a planet is one or two hours west of the sun, it is generally possible to see it low in the eastern sky just before sunrise. The planet will appear in approximately the same part of the sky as that in which the sun will be an hour or two later.



When a planet is one or two hours east of the sun, it is generally posible to see it low in the western sky just after sunset. The planet will appear in approximately the same part of the sky as that in which the sun was an hour or two earlier.

The planets, Mercury and Venus, are most easily seen at or near the

times of their elongations. These occur when the planet is farthest east or west of the sun.

The visibility of a planet is increased if the planet's declination is favorable. The planet's declination should be plus for best visibility in the north temperate zone, and minus for best visibility in the south temperate zone.

A planet is in conjunction with the sun when its path on the diagram intersects the 0° line. The planets, Mercury and Venus, may have both inferior and superior conjunctions. Inferior conjunctions of Mercury and Venus occur when the planet crosses the 0^h line in an east to west direction, while superior conjunctions of Mercury and Venus occur when the planet crosses the 0^h line in a west to east direction. The other planets can have only superior conjunctions.

A planet is in opposition to the sun when its path on the diagram crosses the 12^h line. Two planets are in conjunction with each other when their paths on the diagram intersect. A planet is a morning star when it is on the right of the 0^h line; it is an evening star when it is on the left of the 0^h line.

Most of the planets are easily visible to the naked eye, except when they are close to the sun. Uranus is just visible to the naked eye under favorable circumstances. Neptune is visible in a small telescope or a good pair of field glasses. Pluto can be seen only with the aid of a fairly large telescope.

WASHINGTON, D. C., DECEMBER, 1937.

Planetary Phenomena in 1938

By HERBERT C. WILSON

ECLIPSES

There will be four eclipses during this year, two of the sun and two of the moon.

The eclipse of the sun on May 29 will be total in a rather short path over the southern part of the Atlantic Ocean. Totality will last about 4 minutes, so that the eclipse would be attractive to astronomers were it not for the fact that the path of total eclipse is nearly all over water, with only a few small islands lying within it, and none close to the middle of the path. However, the eclipse might be observed from one of the South Orkney Islands or from the eastern end of the South Georgia Island, if weather conditions should be favorable, which is questionable so far along in the winter season of the southern hemisphere.

The eclipses of the moon will both be total and will both be visible in North and South America.

The following data concerning the eclipses, as well as those concerning the planets, are taken from the *American Ephemeris and Nautical Almanac* for 1938.

Note: In the tables which follow the longitudes are reckoned from Greenwich. The sign + means west for longitude and north for latitude. The sign — means east for longitude and south for latitude. G.C.T. signifies Greenwich Civil

Time, the hour 0 beginning at midnight and the afternoon hours being numbered from 12 to 23.

I. A Total Eclipse of the Moon, May 14, 1938.

This will be visible partly at Washington; the beginning visible generally in the Atlantic Ocean, except the eastern part, North America, except the extreme northern part, South America, Antarctica, the eastern extremity of Australia, the Pacific Ocean, except the northwestern part; the ending visible generally in the central and western part of North America, the western part of South America, Antarctica, the Pacific Ocean, Australia, and the northeastern extremity of Asia.

Circumstances of the Eclipse:

	Greenwich Civil Time			
		d	h	m
Moon enters penumbra	May	14	5	44.3
Moon enters umbra		14	6	56.6
Total eclipse begins		14	8	18.1
Middle of the eclipse		14	8	43.5
Total eclipse ends		14	9	9.0
Moon leaves umbra		14	10	30.7
Moon leaves penumbra		14	11	43.8

Magnitude of the eclipse = 1.102 (Moon's diameter = 1.0)

II. A Total Eclipse of the Sun, May 29, 1938.

The partial phases of this eclipse will be visible over the South Atlantic Ocean, the southeastern part of South America, the southern part of Africa, and a little of the Pacific Ocean off the southwestern coast of South America. The path of totality is wholly in the southern part of the Atlantic Ocean and passes

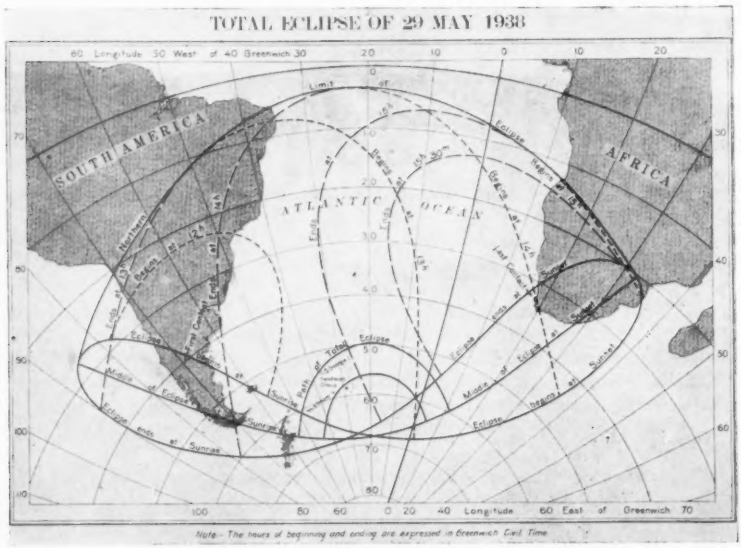


Figure 1

over land only in the South Orkney and parts of the South Georgia and the Sandwich Groups of Islands.

The chart, Figure 1, shows the limits of the area in which the eclipse may be seen. The broken lines show where the eclipse begins at 12^h, 13^h, 14^h, and 15^h, and where it will end at 13^h, 14^h, 15^h, and $15^h\,30^m$, Greenwich Civil Time. To obtain local standard time subtract the number of the hour of the standard time zone in which the observer would be located if observing the eclipse. If the resulting hour is 12 or more it is an afternoon hour and 12 more must be subtracted to obtain ordinary watch time.

Circumstances of the Eclipse:

	G.C.T. d h m	Longitude from Greenwich ° ′	Latitude ° ′
Eclipse begins	May 29 11 46.2	+68 23	−39 19
Central eclipse begins	29 13 22.2	+50 21	−65 40
Central ecl. at local app. noon	29 13 43.1	+26 29	−53 27
Central eclipse ends	29 14 17.6	− 8 33	−61 20
Eclipse ends	29 15 53.5	−16 23	−32 21

The duration of totality along the middle line of the path varies from $3^m\,33^s$ near the South Orkney Islands to $3^m\,54^s$ near the South Georgia Island, reaching its maxmium of $4^m\,4^s$ near the top of the curve in about longitude 22° west from Greenwich, where no islands are mapped.

III. A Total Eclipse of the Moon, November 7-8, 1938.

This will be visible only in part at Washington, the beginning visible generally in Eurasia, the western part of Australia, the Indian Ocean, Africa, the Atlantic Ocean, the Arctic Ocean, the extreme northeastern part of North America, and the extreme eastern part of South America; the ending will be visible generally in central and western Asia, the western part of the Indian Ocean, Europe, Africa, the Atlantic Ocean, the Arctic Ocean, North America, except the extreme western and northwestern part, and South America.

Circumstances of the Eclipse:

	Greenwich Civil Time d h m
Moon enters penumbra	Nov. 7 19 39.0
Moon enters umbra	7 20 40.8
Total eclipse begins	7 21 45.0
Middle of eclipse	7 22 26.2
Total eclipse ends	7 23 7.5
Moon leaves umbra	8 0 11.9
Moon leaves penumbra	8 1 13.9

Magnitude of the eclipse = 1.359 (Moon's diameter = 1.0)

IV. A Partial Eclipse of the Sun, November 21-22, 1938.

This will be visible generally over the northern part of the Pacific Ocean. The beginning of the eclipse will be visible about sunset over most of Alaska and the extreme western parts of North America. It will be visible at sunrise in the extreme northeastern parts of Asia, including the northern islands of Japan.

The chart, Figure 2, shows the area over which the eclipse may be seen, the broken lines showing where the eclipse will begin at 22^h, 23^h, 0^h, and 1^h, and when it will end at 23^h, 0^h, 1^h, and $1^h\,30^m$, Greenwich Civil Time.

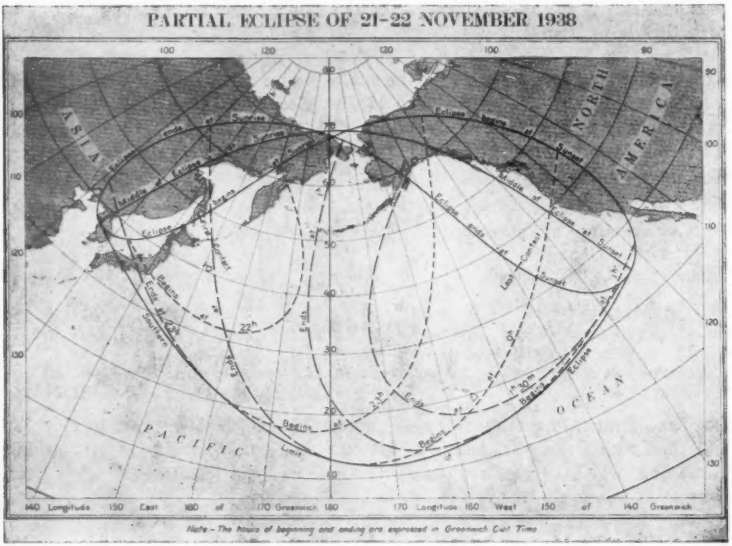


FIGURE 2

Circumstances of the Eclipse:

	G.C.T.	Longitude from Greenwich	Latitude
	d h m	° ′	° ′
Eclipse begins	November 21 21 45.0	−143 58	+48 0
Greatest eclipse	21 23 52.0	+162 3	+68 57
Eclipse ends	22 1 59.1	+138 25	+35 41

Magnitude of greatest eclipse = 0.778 (Sun's diameter = 1.0)

THE PLANETS

Mercury begins the year in Sagittarius, retrogrades until January 9, then moves eastward close to the ecliptic until April, when its path forms an S in the constellation Pisces. It then proceeds eastward, not far from the ecliptic, until August and September, when the path forms a closed loop something like a broad reversed figure 6 in Leo. For the rest of the year the motion of Mercury is about east-southeast through Virgo and Libra until December 4, when another reversed motion is begun in Sagittarius, ending the year about 19° northeast of Antares (α Scorpii).

The planet will be at superior conjunction (behind the sun) on March 8, June 22, and October 10. It will be at inferior conjunction (this side of the sun) on April 21, August 28, and December 14.

Mercury will be most easily observed during the week before and the week after each time of "greatest elongation" east and west of the sun. These times are given in the following table:

GREATEST ELONGATIONS OF MERCURY FROM THE SUN

As Morning Star			As Evening Star		
Date	G.E. West	Stellar Mag.	Date	G.E. East	Stellar Mag.
January 21	24° 17′	+0.1	April 2	19° 5′	+0.1
May 19	25 37	+0.8	July 31	27 15	+0.6
September 13	17 54	0.0	November 25	21 51	−0.1

There will be an occultation of Mercury by the moon on April 2, the planet being 10′ north of the moon's center at $5^h\,51^m$ G.C.T., as seen from the earth's center. The occultation could be observed from the observatories at Hyderabad and Madras, India, if means could be devised for seeing the planet clearly in midday only 19° away from the sun.

Venus is on the farther side of her orbit from the earth, coming to superior conjunction, i.e., behind the sun, on February 4. From then on it will be evening star, moving eastward approximately along the ecliptic, from Capricornus through Aquarius, Pisces, Aries, Taurus, Gemini, and all the other zodiacal constellations in succession until November, when her apparent path will turn northwest from Scorpio into Libra until December 11, then eastward for the rest of the year. The planet will be at inferior conjunction in longitude, between the earth and sun, on November 20 at 6^h G.C.T., Venus passing about 3° south of the sun's center, but being invisible because of the glare of the sun.

Venus will be at greatest brilliancy as evening star on October 16, stellar magnitude −4.3, and as morning star December 30, stellar magnitude −4.4.

Venus will be at greatest elongation east of the sun 46° 19′ on September 11, when it will be in the constellation Virgo, about 10° east and 5° south of the star Spica, which star the planet will then transcend in brilliancy about 15 times.

Mars begins the year in Aquarius and will move steadily eastward along the ecliptic without any retrograde movement, ending the year at about the eastern border of the constellation Virgo. The planet will be on the farther side of its orbit from the earth during most of the year, being in conjunction with the sun on July 24, and so will not be in especially favorable position for observation during this year. The distance of Mars from the earth will increase from about 154,000,000 miles on January 1 to 247,000,000 miles on August 5, then decrease to about 181,000,000 miles on December 31, and the apparent diameter of the planet's disk as seen in the telescope on the corresponding dates will be 5″.6, 3″.5, and 4″.8.

Jupiter's course begins near the west boundary of the constellation Capricornus, moves easterly along the ecliptic into Aquarius until June 22, then westerly until October 19, and again easterly until the end of the year, still in Aquarius. The planet will be in conjunction, behind the sun, January 29; at quadrature 90° west of the sun May 22; at opposition to the sun August 21; and at quadrature 90° east of the sun November 16. The best time for observing Jupiter will therefore be during the late summer, the autumn, and the early winter months.

The apparent diameter of Jupiter's disk at opposition, when nearest to the earth, will be about 46″; on May 1 it will be 35″, and on December 31 about 33″.

The belts of Jupiter are always interesting to study as they change from time to time. The planes of the satellite orbits pass very close to the earth at the time of opposition this year, so that the projections of the orbits are approximately straight lines, confusing or coinciding with each other. The *American Ephemeris* therefore gives no diagram of them. The four bright satellites all transit the equa-

torial belt and disappear and reappear by occultation at the same points at the edge of the planet's disk at each circuit around the planet.

No occultation of Jupiter by the moon will occur this year, since the moon passes about 6° to the north of the planet each month.

The stellar magnitude of Jupiter will change from —1.5 in February to —2.4 in August and back to —1.7 at the end of the year.

Saturn is about 2° south of the ecliptic, near the vernal equinox, in the constellation Pisces, and will move northeastward, approximately on a parallel to the ecliptic until August 1, then will retrace part of its course until December 16, moving slowly eastward again during the last two weeks of the year.

The planet will be at opposition to the sun on October 8, at quadrature 90° west of the sun July 10, and approaching quadrature 90° east of the sun at the end of the year. The best time for observing Saturn will be during the autumn and winter months.

The stellar magnitude of Saturn will vary from +1.0 in April to +0.4 in October and back to +0.9 in December, so that the planet will appear rather brighter than the average first magnitude star. Its apparent polar diameter will vary between approximately 14″ and 18″ during the year.

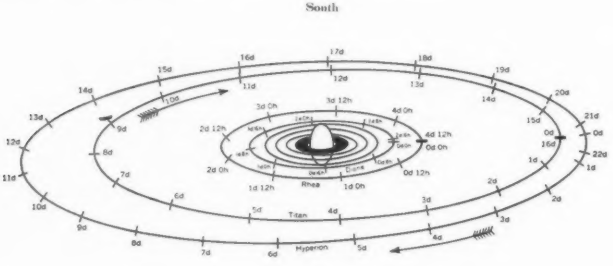


FIGURE 3

Apparent orbits of the seven inner satellites of Saturn, at date of opposition, October 8, 1938, as seen in an inverting telescope, and elongated in the ratio of two to one in the direction of their minor axes.

The rings and orbit system of the satellites have opened up a little as compared with last year, as shown by the diagram, Figure 3. In this diagram the vertical scale is double the horiontal scale, to relieve the inner orbits from confusion. The orbits of the outer two satellites, Iapetus and Phoebe, are not shown in the diagram on account of their size.

Uranus will be at opposition November 8 and so can be seen, with a telescope, best during the autumn and winter months. The apparent diameter of this planet at opposition will be only 3″.7, so that but little detail can be seen upon its surface. The four satellites are too faint to be seen with small telescopes. The stellar magnitude of Uranus at opposition will be 6.0.

The path of the planet for the year will be about 9° long, just south of the ecliptic in the constellation Aries, roughly 10° southeast of the star α Arietis. It will move westward until January 18, then eastward until August 24, then westward for the rest of the year.

There will be occultations of Uranus by the moon on July 22, August 18, September 14, October 11, and December 5. Those which occur on August 18, September 14, and December 5 will be visible in parts of the United States. The following data are given in the *American Ephemeris*:

OCCULTATIONS OF URANUS BY THE MOON

Date	Calculated for	Immersion Greenwich Civil Time h m	Emersion Civil Time h m
Aug. 18	Washington	6 8.3	7 0.6
18	Long. 72° 30′; Lat. 42° 30′	6 15.8	7 12.2
18	Long. 91 0; Lat. 40 0	6 1.3	6 58.6
18	Long. 120 0; Lat. 36 0	6 1.2	6 51.8
Sept. 14	Long. 72 30; Lat. 42 30	13 35.7	14 31.4
14	Long. 91 0; Lat. 40 0	13 33.2	14 24.2
Dec. 5	Long. 91 0; Lat. 40 0	9 55.9	10 33.9

Neptune will be at opposition to the sun March 11 and so will be best seen during the winter and spring months. Its course is only about 6° long, beginning about 5° northwest from the star β Virginis, moving northwesterly about 4°, then southeasterly about 6°, ending the year about 3° northwest of β Virginis. The stellar magnitude of Neptune at opposition will be 7.7. The one satellite of Neptune is too faint to be observed with small telescopes.

Planet Notes for February, 1938

By R. S. ZUG

Note: Greenwich Civil Time is employed, unless otherwise stated. In order to obtain Eastern Standard Time, subtract 5 hours; Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken from the *American Ephemeris*.

Sun. The positions of the sun for February 1 and February 28, respectively, are: $\alpha = 20^h\ 55^m.7$, $\delta = -17°\ 20'.6$; $\alpha = 22^h\ 41^m.5$, $\delta = -8°\ 17'.5$. The sun is moving in a northeast direction through the constellation Capricornus, and on February 16 it passes into the constellation Aquarius. Values for the equation of time are as follows:

Date 1938	Equation of Time (Mean - Apparent) m s	Date 1938	Equation of Time (Mean - Apparent) m s
Feb. 2	+13 44	Feb. 18	+14 8
6	+14 9	22	+13 44
10	+14 21	26	+13 11
14	+14 21	Mar. 1	+12 39

Moon. Phenomena of the moon will occur as follows:

		h m
First Quarter	Feb. 8	0 32
Full Moon	14	17 14
Last Quarter	22	4 24
New Moon	Mar. 2	5 40
Perigee	Feb. 12	6
Apogee	24	1

Mercury. Mercury was at greatest western elongation on January 20, and its elongation is now decreasing. The planet rises on the average an hour before the

sun, but, due to its low declination, has attained only a low altitude by sunrise. It is evident that Mercury is unfavorably situated for northern observers.

Venus. Superior conjunction for Venus occurs February 4, 3^h, at which time the planet becomes an evening star but will not be conspicuous during this month. On February 28 its eastern elongation will have reached only 6° so that it will set soon after the sun.

Mars. Mars is still an evening star but its elongation is decreasing, and by nightfall it is fairly low in the western sky, and poorly placed for observation. On February 2, 20^h, it passes 2° north of Saturn, and thereafter moves rapidly to the eastward among the stars.

Jupiter. Conjunction having occurred January 29, Jupiter is a morning star, but close to the sun. The sun quickly moves eastward with respect to Jupiter so that the latter should be visible toward the end of February, low in the southeastern sky just before sunrise.

Saturn. February 1 finds Saturn situated about 3° southeast of the vernal equinox and a little over 3^h east of the sun. The most interesting aspect is the conjunction with Mars, mentioned above. The rings continue inclined to the line of sight by an angle of about 3°, the southern side of the rings now being visible. While this results in a less spectacular view of the rings themselves, it perhaps facilitates observation of the inner satellites, of which Tethys, Dione, and Rhea should at times be visible with a 5- or 6-inch glass, and no moon. Their magnitudes are, respectively, 10.5, 10.7, and 10.0.

Uranus. The planet Uranus is well placed for early evening observation, meridian passage occurring about the time of sunset, during February. Quadrature occurred January 30. On February 1 the planet is situated a little over a half degree southeast of the sixth magnitude star, 29 (ω) Arietis, and should be distinguishable as a small disc (diameter 1".7) with apertures over 3 inches. It moves eastward about a half degree during February.

Neptune. Neptune is in the constellation of Leo, the position for February 1 being $\alpha = 11^h\,27^m\,45^s$, $\delta = 4°\,42'.7$. At this time it is $4^m\,32^s$ west, and 1° 19′ north, of the 5.8 magnitude star 89 Leonis. Neptune is in slow retrograde motion during the month of February.

Asteroid Notes

By HUGH S. RICE

The Reinmuth Object, 1937 UB

In these years of modern astronomical research our knowledge of asteroids as well as of meteors is enlarging rapidly, and we are learning of asteroids that come much closer to the earth than any we had ever known before. Just recently Reinmuth of Heidelberg has again caught with the astro-camera the trace of an extraordinary minor planet that approaches the earth's orbit much nearer than Adonis—which lately has been holding the record for nearness. The new planet is known as 1937 UB.

Reinmuth, photographing in southeastern Pisces, on October 28 obtained a sharp stellar trail 27 mm long on each of two plates exposed simultaneously for two hours. During the exposure it moved about 42′ of arc. However the *direction*

of motion was not determined—it was not known which end of the trail was the beginning and which the end. On the following day the search for the object was undertaken during a short break in the clouds, at both ends corresponding to the extrapolated motion. Reinmuth with the Bruce telescope gave a 23-minute exposure beyond the position of the west end of the trail, and Wempe with the 6-inch gave a 30-minute exposure at the east end; but no suspicious image was found.

Search was continued on October 30, but from later observations at Sonneberg (south of Jena) it developed that the object had moved so fast westwardly that it could not possibly have been found on these later plates. Further work was rendered impossible by cloudy weather.

A parabolic orbit was computed by Vick on November 15 from the scanty observations, and published by the Astronomisches Rechen-Institut. A special ephemeris gave the closest approach (October 30) as 724,600 miles. The magnitude at discovery was given as 10. In Vick's first ephemeris the magnitude for October 30 was 5.5, but it was pointed out by him that the magnitude needed to be highly corrected for *phase*. The published exact positions by observer Morgenroth in Sonneberg extended through four days, and were derived with the micrometer from three or four B.D. comparison stars. Along with them are about the last observations of the late Spanish astronomer J. Comas Solá, whose passing in Barcelona we note with regret, since he was a regular contributor to professional asteroid observations.

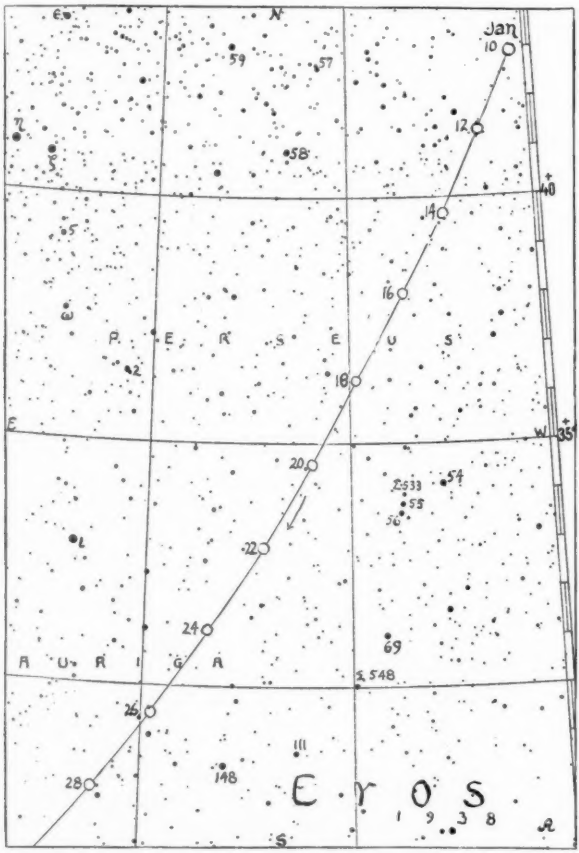
On November 19 new [elliptic] elements by Gondolatsch were published by the R.I. The observations of Sonneberg had been remeasured more precisely. Gondolatsch states that the orbit determinations left the geocentric distance very uncertain so that an arbitrary value was put in for the middle observation, in order that the elliptic orbit could be completed. The original observations were not given very exactly; the Sonneberg positions reported on November 21 were made with a short-focus lens (25 cm) and the planet images were mostly on the edges of the plate and so distorted that correct positions were difficult to determine. Using corrected positions, new elliptic elements were computed by Gondolatsch on November 25, and another set two days later from positions on Harvard, Heidelberg, and Sonneberg plates.

On December 1 Gondolatsch states that as there is no prospect of finding the planet from the present data, he is asking observers to search any possible old plates for further positions, with the help of the new ephemeris which he gives. This has positions for every hour of each of three days, October 28 to October 30. It is noticed in his ephemeris that the closest approach to the earth took place at 17^h U.T., October 30, *with the planet only 362,300 miles from the earth!* It is, however, to be stressed that the figure is highly uncertain on account of the paucity of good observations and the lack of separation of these in time. If it be true, it means that the asteroid was only about 109,000 miles farther from the earth than the moon's greatest distance. As far as known no estimates of the size of this diminutive world have been published. Such discoveries point out the fact that likely there are many minute asteroids moving in interplanetary space, of whose presence we are as yet unaware.

Eros

The orbit of minor planet 433 Eros is so exactly known that the planet is following the ephemeris with only very small residuals. Our chart shows the apparent path among the stars around the time of its closest approach to the earth on

January 14. Positions are for 0^h U.T., which corresponds to 7:00 P.M. E.S.T. (6:00 P.M. C.S.T., etc.) *of the day before.* The term Universal Time is now supplanting Greenwich Civil Time in professional astronomical circles. It will be seen that Eros moves rapidly in this part of its orbit, so that one chart can show



PATH OF EROS AMONG THE STARS IN JANUARY, 1938

but a small portion of its path during the apparition. Perihelion is reached on February 1. When nearest the earth the distance is about 19,900,000 miles. The magnitude being about 8.6, it is within reach of small instruments.

There are now 1417 asteroids with orbits sufficiently known that the elements and ephemerides can be computed by the Astronomisches Rechen-Institut.

Hayden Planetarium, American Museum of Natural History,
New York City, December 22, 1937.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In a search through journals and other publications for all references to long-enduring meteor trains, I came upon the Bulletins of the Kwasan Observatory, in Japan. Examining the incomplete file here, I was immediately struck by the fact that in Japan, during the past five years, systematic meteor work had been prosecuted upon a really large scale. With commendable good judgment most of the publications are in English, the tables having superimposed Japanese headings; also part of the text and many notes are in that language. However, in most cases it is so presented that the meaning is clear. The form for the daily rates is that which I have used in publications of the A.M.S., full data being given. Tables for radiants with necessary notes are also found. The serial number of their radiants had reached 1582 in May, 1936. Short tables are also published at intervals containing the full descriptions and coördinates of apparent paths of bright meteors seen during the previous couple of months or so. The heights of many isolated fireballs and bright meteors are computed. In 1933 an extensive campaign for work on the Leonids was carried out. Besides about 40 meteor observers, members of their observing section, they had 62 school or other groups out. It was estimated that a thousand persons took part. In 1934, for the Leonids, 27 persons and 7 groups observed a total of 282 hours, recording 5867 meteors. Bul. No. 298, Table VII, gives the real paths of 30 meteors, from this work. For those 25 which are probably Leonids I have taken the average heights, which are: for the beginning point 134.3 km, for the ending point 88.9 km. The results are of special interest when compared to those derived from A.M.S. work which were criticised on, so far as I can make out, purely theoretical grounds by Öpik, who said that the A.M.S. results were affected by a large systematic error which made them too high. The results in question, based on work in 1932, 1933, and 1934 are: for 220 Leonids, beginning point 123.9 km; for 232 Leonids ending point 91.8 km. The reader may draw his own conclusions, the Japanese figures being merely another independent confirmation of the heights of these points for Leonid meteors due to A.M.S. observations. Returning to the Kwasan Bulletins, in addition, photographic and telescopic meteor work is discussed, and, in at least one case, excellent drawings of a long-enduring train are given. It is to be hoped that the present war will not break up this active Japanese group which has accomplished so much. Any person seriously interested in theoretical meteor work or desirous of comparing international results, should subscribe to these Bulletins, the price of which was, and probably still is, very reasonable.

Some years ago I stopped publishing tabular data on daily rates except for the Perseid and Leonid epochs. This year, due to the poor weather conditions or moonlight, comparatively little was received from our members which dealt with either stream. In compiling this, as there was not a great amount of other such rates at hand, I decided to combine most of it into the following table. A study of this, combined with what was published in the October number on the Perseids based on reports from non-members, will show that the 1927 return of that stream was below average. Little of striking interest was reported, even as to single

meteors or fireballs. At this writing the only reports on the Leonids have come from Baltimore, New Haven, and Santa Barbara. At New Haven a large group observed under V. Anyzeski who is ably directing our work in that region. Despite brilliant moonlight, more Leonids were seen between 15 and 16 hours on both November 14-15 and 15-16 than might have been expected. His group observed for heights in conjunction with one at Vassar College where the results are now being reduced, I am informed. At Santa Barbara we have an active observer, Wm. R. Stone, who writes me he has passed his 85th birthday in September. This did not in the slightest prevent him from observing the Leonids for three nights in succession, the longest observing period being 4½ hours, nor was he discouraged because he saw no meteor in the first two hours of his watch! He was rewarded by 21, however, later. His plotting is good and his records are in perfect form. What an example he sets to our younger members. Incidentally he was ready for the earlier showers but clouds or fog prevented effective observations. On the whole the Leonids did better than we expected. Moonlight also ruined the Orionids, and so far our only full reports are from Anyzeski and E. Loreta in Italy. The latter remarks that, from the large number of bright Orionids seen, it may be concluded that but for the moon, the return would have been a strong one. It is too bad that Perseids, Orionids, and Leonids were all largely spoiled in 1937. The Geminids will not suffer from moonlight at least. It is but fair to say that we have two large and active groups, the Missouri-S. Illinois, and the Wisconsin-N. Illinois, whose reports do not generally come in until after the end of the year. This explains why they do not appear in the appended table.

The writer is actively pushing his researches into long-enduring meteor trains, and believes that he has been able to unearth the larger part which occur in the better known scientific publications. However, some have been missed. Will any reader therefore please send me at once any new data on this subject or be good enough to give me references where such accounts can be found? Such assistance would be greatly appreciated, as accounts buried in journals, not likely to be consulted, will have been overlooked.

Observer and Station	Date 1937	Began	Ended	Total	Met.	F.	Rate
(*1) V. Anyzeski, New Haven, Conn.	Apr. 20	12:12	14:12	120	7	0.2	3.5
(*2) J. Neale, New Haven	Apr. 20	12:12	14:12	120	6	0.2	3.0
(*3) F. Burnham, New Haven	Apr. 20	12:12	14:12	120	4	0.2	2.0
(*4) Rodemacher, New Haven	Apr. 20	12:12	14:12	120	7	0.2	3.5
(*5) V. Anyzeski, New Haven	July 4	10:30	12:40	130	14	1.0	6.5
(*5) J. Neale, New Haven	July 4	10:30	12:40	130	9	1.0	4.2
(*5)	July 7	11:00	13:00	120	10	0.7	5.0
(*5) V. Anyzeski, New Haven	Aug. 29	11:00	12:05	65	7	0.7	6.5
(*5) J. Neale, New Haven	Sept. 6	9:05	10:45	100	9	0.9	5.4
(*5) V. Anyzeski, New Haven	Sept. 6	10:00	12:30	150	16	0.9	6.4
(*5)	Sept. 8	8:30	13:15	285	51	1.0	10.7
(*5)	Sept. 9	8:20	13:25	305	54	1.0	10.8
(*5)	Sept. 10	8:25	11:15	170	18	0.7	6.4
(*5)	Oct. 16	12:00	16:00	240	26	0.6	6.5
(*5)	Oct. 17	12:00	14:45	165	4	0.2	1.5
(*5)	Oct. 20	12:00	15:05	185	19	0.4	6.2
(*5) J. Neale, New Haven	Oct. 20	12:25	15:05	160	9	0.4	3.4
(*5) V. Anyzeski, New Haven	Oct. 24	11:45	13:05	80	6	0.6	4.5
(*6)	Oct. 30	9:00	10:00	60	11	1.0	11.0
(*6)	Oct. 30	12:00	14:25	165	37	1.0	13.5
(*5) J. Neale, New Haven	Oct. 30	12:05	14:30	145	14	0.9	5.8
(*5) V. Anyzeski, New Haven	Nov. 6	8:00	9:10	70	14	0.9	12.0
(*7)	Nov. 14	12:00	16:00	240	35	0.3	8.8
(*7) M. Corbett, New Haven	Nov. 14	12:00	16:00	240	21	0.3	5.2

Observer and Station	Date 1937	Began	Ended	Total	Met.	F.	Rate
(*7) J. Neale, New Haven	Nov. 14	12:00	16:00	240	25	0.3	6.2
(*7) F. Burnham, New Haven	Nov. 14	12:00	16:00	240	8	0.3	2.0
(*7) Miss G. Rodemacher, New Haven	Nov. 14	12:00	16:00	240	36	0.3	9.0
(*7) Mrs. Partridge, New Haven	Nov. 14	12:00	16:00	240	27	0.3	6.8
(*7) R. Burns, New Haven	Nov. 14	12:00	16:00	240	27	0.3	6.8
(*7) W. Wentworth, New Haven	Nov. 14	12:00	16:00	240	30	0.3	7.5
V. Anyeski, New Haven	Nov. 15	12:00	16:00	240	26	0.2	6.5
J. Neale, New Haven	Nov. 15	12:00	16:00	240	16	0.2	4.0
(*5) J. L. Black, Cleveland, Ohio	Aug. 12	11:21	13:51	150	23	0.7	9.2
(*8) E. F. Bowman, Kansas City, Kan.	Aug. 12	11:50	16:08	258	91	0.7	21.2
(*8) J. Borroughs, Kansas City	Aug. 12	13:16	15:50	214	61	0.7	17.1
(*8) Mrs. J. Borroughs, Kansas City	Aug. 12	13:06	15:56	170	53	0.7	18.7
(*8) Mrs. L. Straight, Kansas City	Aug. 12	11:52	16:10	258	72	0.7	16.3
(*9) F. Brown, Elwood, Kan.	Aug. 12?	10:50	12:00	70	58		
(*5) L. Arslonian, San Jose, Calif.	Jan. 2	8:35	10:40	125	4	0.9	
(*5)	Aug. 11	9:40	11:30	110	8	0.8	
(*5)	Aug. 12	9:40	12:25	155	17	0.8	
(*10) Mrs.L.R.Garland,Salisbury,N.C.	Aug. 11	9:00	10:00	60	40		
J. W. Graham, Salem, Ore.	Aug. 11	12:00	14:00	120	129		64.5
(*9)	Aug. 11	14:00	15:00	60	100		
(*5) G. Green, Pittsfield, Mass.	July 26	10:45	15:00	255	33	0.9	7.8
(*5)	July 31	12:45	15:25	160	19	0.3	7.1
(*11)	Aug. 9	9:44	14:23		35	1.0	
(*12) D. Hunter, Eugene, Ore.	Aug. 10	12:30	15:30	180	69	1.0	23.0
(*12)	Aug. 11	12:15	15:45	210	91	1.0	26.0
(*12)	Aug. 12	12:38	15:38	180	70	1.0	23.3
(*8) J. Leerman, Baltimore, Md.	Jan. 3	12:40	14:40	120	6		3.0
(*8)	Jan. 4	12:55	13:55	60	3		3.0
(*8)	Aug. 12	13:00	15:10	130	40		18.5
(*8)	Aug. 13	13:00	15:00	120	43		21.5
(*8)	Aug. 14	13:50	14:55	65	16		14.8
(*8)	Aug. 15	13:50	14:55	65	11		10.2
(*8)	Aug. 16	13:30	14:30	60	10		10.0
(*8)	Aug. 27	12:45	14:15	90	9		6.0
(*8)	Aug. 28	11:25	12:25	60	6		6.0
(*8)	Nov. 13	14:00	15:00	60	8		8.0
(*8)	Nov. 14	13:00	13:30	30	2	0.1	4.0
(*8)	Nov. 15	13:45	15:15	90	16		10.7
(*8) E. Loreta, Bologna, Italy	Mar. 2	7:30	9:55	125	20		9.6
(*8)	Mar. 6	8:00	9:55	100	9		5.4
(*8)	Mar. 15	8:00	9:55	100	12		7.2
(*8)	Apr. 11	8:00	9:25	75	4		3.2
(*8)	Apr. 12	8:00	9:25	75	11		8.8
(*13)	May 7	12:40	14:50	130	25		11.5
(*14)	May 8	12:50	14:50	120	27		13.5
(*15)	May 9	13:20	14:45	85	15		10.6
(*16)	Aug. 6	8:30	11:55	175	34		11.7
(*16)	Aug. 7	8:30	12:25	125	42		20.2
(*17)	Aug. 9	8:30	12:25	125	56		26.9
(*18)	Aug. 11	8:30	13:25	250	166		39.9
(*19)	Aug. 12	8:30	11:25	150	73		29.2
(*20)	Aug. 13	9:30	12:55	175	75		25.7
(*21)	Aug. 14	9:00	12:25	175	62		21.3
(*22)	Aug. 15	11:00	12:25	75	37		29.6
(*23)	Oct. 12	11:30	12:25	50	10		12.0
(*24)	Oct. 19	14:00	15:25	75	16		12.8
(*25)	Oct. 20	13:30	14:25	75	6		4.8
(*26) D. Faulkner, Deland, Fla.	Apr. 20	10:20	16:10	311	37	1.0	
James Melville, Denver, Colo.	Aug. 11	8:00	10:30	150	12	1.0	4.8
(*8) Miss D. C. Schoof, Butler, N. J.	Aug. 11	10:30	12:00	90	34	1.0	22.7
(*27) E. S. Rodemacher, Cutchogue,	Aug. 14	11:00	14:00	180	19	1.0	6.3
(*5) Mrs. Rodemacher, " N. Y.	Aug. 14	10:00	12:18	138	18	1.0	7.8

Observer and Station	Date 1937	Began	Ended	Total	Met.	F.	Rate
Miss M. Shapinski, Louisville, Ky.	Aug. 11	10:00	12:18	138	38	1.0	16.5
W. L. Moore, Louisville	Aug. 11	10:00	12:18	138	38	1.0	16.5
J. Landau, Louisville	Aug. 11	10:00	12:00	120	36	1.0	18.0
Miss M. Shapinski, Louisville	July 27	12:00	13:00	60	5		5.0
(*29) Louisville Astr. Society	June 28	11:00	12:30	90	90	0.4	4.3
(*5) F. W. Smith, Vineland, N. J.	Jan. 4	10:00	11:00	60	3	1.0	3.0
(*5)	Mar. 7	9:00	10:30	90	3	1.0	2.0
(*5)	May 7	13:00	15:00	120	7	1.0	3.5
(*5)	July 29	9:30	10:40	70	5	1.0	4.3
(*30) C. H. Smith, Waterloo, N. Y.	Aug. 11	10:35	15:10	180	116	1.0	38.7
(*31)	Aug. 12	10:40	12:15	90	52	0.8	34.7
(*32)	Aug. 13	11:33	13:15	90	39	1.0	26.0
(*33)	Aug. 14	11:40	12:40	60	20	1.0	20.0
(*5) H. Stackpole, San Jose, Calif.	Aug. 12	9:40	15:15	275	33	?	?
(*5)	Aug. 13	9:45	11:40	115	15	?	?
(*8) R. E. Stevens, Daytona Beach, Fla. "	11	12:35	16:15	220	134	1.0	36.5
(*34) Group at Daytona Beach				220			
(*5) F. W. Smith, Vineland, N. J.	Oct. 6	9:00	10:00	60	5	1.0	5.0
(*5)	Oct. 25	10:00	11:00	60	11	0.8	11.0
(*35) W. R. Stone, Santa Barbara,	Nov. 13	12:00	16:00	240	11	0.5	
(*36) California	Nov. 14	13:00	16:30	270	21	0.4	
(*5)	Nov. 15	13:00	15:15	135	4	0.3	
(*37) T. K. Tomkins, North Hills, Pa.	Aug. 6	12:25	14:25	120	11	0.7	5.5
(*38)	Aug. 14	10:55	12:15	80	9	1.0	6.8
(*5)	Oct. 8	11:50	13:05	75	9	0.9	7.2
(*5)	Oct. 16	12:10	13:40	90	3	1.0	2.0
B. S. Whitney, Norwall, Okla.	May 1	11:25	12:45	80	5	1.0	3.8
	May 8	11:55	13:55	110	15	1.0	8.2
Four-fifths of Whitney's plotted	June 4	10:35	12:35	120	15	1.0	7.5
	July 4	10:05	13:23	153	19	1.0	7.5
	July 6	9:20	12:00	142	25	1.0	10.6
	July 10	9:20	10:50	90	8	1.0	5.3
	July 17	13:37	15:58	141	25	0.9	10.6
	July 26	9:02	10:02	60	8	1.0	8.0
	July 27	9:30	10:45	75	17	0.9	13.6
	Aug. 3	11:03	12:39	96	28	1.0	17.5
	Aug. 4	10:24	13:24	180	53	1.0	17.7
	Aug. 5	10:18	10:50	32	7	0.8	13.1
	Aug. 6	9:48	13:23	180	49	1.0	16.3
	Aug. 7	10:20	11:05	45	11	0.8	13.7
E. Loreta, Bologna, Italy	July 6	9:00	10:25	75	9		7.2
	July 10	9:00	9:55	50	7		8.4
Loreta's part plotted	July 12	9:00	9:55	50	5		6.2
	July 13	9:00	9:55	50	7		8.8
1 Perseid	July 28	8:30	9:25	50	11		13.8
2 Perseids	July 29	8:30	9:25	50	12		15.0
2 Perseids	Aug. 1	8:30	9:25	50	14		16.8
6 Perseids	Aug. 2	8:30	9:55	75	17		13.6
38 Perseids	Aug. 3	8:30	13:25	250	96		23.0
17 Perseids	Aug. 4	8:30	11:55	175	40		13.7
14 Perseids	Aug. 5	8:30	11:55	175	37		12.7
(*5) J. Neale, New Haven, Conn.	July 8	11:00	13:00	120	10	0.7	5.0

Notes

1. Observed radiant.
2. Observed Northeast.
3. Observed North.
4. Observed Southeast.
5. Plotted.
6. 44 plotted.
7. Average rate 6.5.
8. Meteors were counted only.
9. Two observers.
10. Six observers.
11. 23 plotted.
12. Plotted. Others seen!
13. 10 Aquarids.
14. 6 Aquarids.
15. 1 Aquarid.
16. 19 Perseids.

17. 36 Perseids.
18. 115 Perseids.
19. 52 Perseids.
20. 44 Perseids.
21. 34 Perseids.
22. 13 Perseids.
16 to 22. 212 plotted.
23. 4 Orionids.
24. 14 Orionids.
25. 6 Orionids.
26. 3-4 observers.
27. 6 earlier counted only.
29. Counted only, av. rate of 12 obs.
30. 94 Perseids, counted only.
31. 37 Perseids, counted only.
32. 29 Perseids, counted only.
33. 11 Perseids, counted only.
34. 64 plotted.
35. All seen after 13^h, plotted.
36. All seen after 15^h, plotted.
37. 3 Perseids, plotted.
38. 6 Perseids, plotted.

Flower Observatory, Upper Darby, Pennsylvania, 1937 December 2.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
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President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver
Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California at Los Angeles

Czechoslovakian Tektites and the Problem of their Origin: An Up-to-date Résumé of this Question*

By JAN KASPAR,
Narodni Museum, Prague, Czechoslovakia

The Czechoslovakian tektites were the first tektites known from European localities. These localities are situated in the western part of the Czechoslovakian republic, on the 49° northern parallel, between about the 14° eastern meridian, west of České Budějovice, and the 16° 30′ eastern meridian, southeast of Třebič

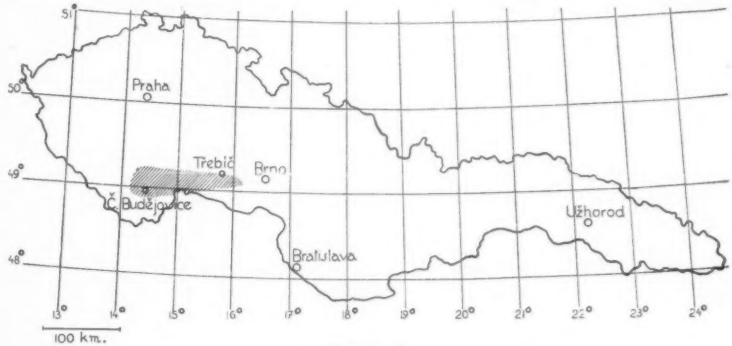


FIGURE 1
AN OUTLINE MAP OF CZECHOSLOVAKIA, SHOWING THE DISTRIBUTION OF THE TEKTITES

*Communicated by F. W. Sassirer, Prague VII, 751, Czechoslovakia, and read by title at the Fifth Annual Meeting, Colorado Museum of Natural History, Denver, June 22 and 23, 1937.

(see the map, Fig. 1). Unlike other tektite finds, these occur in places characterized by numerous outcrops, agricultural operations, clay and sand pits, and gravel holes; and they have been known for a very long time. Ten years before the general tektite theories were put forward by R. D. M. Veerbeek, F. E. Suess, and P. G. Krause, the Czechoslovakian tektites had been studied (in 1889) by the engineer Bareš. These tektites have a special name of their own, *moldavites* or *czech-vltavines*, so-called after the River Moldau-Vltava. Since the time of Bareš, there has developed in Czechoslovakia a very voluminous and original literature on moldavites, mainly in the Czech language. This fact is the reason that this literature has not had an important influence on the general literature on tektites. The up-to-date results of the local researches regarding the special territorial distribution of these tektites can be found in a recent paper by Professor Oswald (*Časopis Národního Musea*, Praha, 1936). Regarding the latest and most important theoretical questions, a most instructive book by the engineer F. Hanuš (*Česka Akademia*, Praha, 1928) may be consulted.

Bareš's principal problem was to prove that the old notion, that these glasses are of artificial origin, is wrong. He showed that artificial glasses melt at a temperature of 1250° Celsius. Moldavites, however, have their melting point at 1400° Celsius. Moreover, the theory of their artificial origin can hardly be maintained in view of the distribution of the moldavites in a territory 150 km. in length and 34 km. in breadth. Furthermore, the thoroughly homogeneous chemical composition of these glasses is another important point which militates against the theory of their artificial origin. The latest chemical analyses which have been made of moldavites will soon be published by Dr. R. Novaček (*Česka Akademia*, Praha). In these investigations, the previously mentioned high melting point has been confirmed; a hardness of 31 corundum units has been found, *i.e.* a hardness greater than that of synthetic glasses; the index of refraction has been fixed at between 1.48 and 1.49, and this is not so high as that of artificial glasses (1.5); and the chemical composition has been ascertained to be quite at variance with that of any kind of artificial glass. As concerns their geological distribution, moldavites have been discovered beneath the cultivated layer of the soil, in the soil, gravel, sand, and clay of strata which had not been previously disturbed in any way. These strata belong probably to the latest Tertiary period. With reference to their forms, all moldavites may be classified into two groups, to wit:

(1) *Complete pieces*, which have rounded forms like balls, burrs, drops, and the like. Only ten per cent of all finds are found as complete pieces.

(2) *Fragments*, which occur, *first*, as broken parts of the aforementioned complete pieces, and, *second and mainly*, as broken pieces and chips or splinters of great blisters (blebs or bubbles), which have never been found entire. It is evident that both the *complete pieces* and the *fragments* have been formed from a fused mass. Thin polished plates show a peculiar internal fluidic structure.

It is the usual custom in the literature to apply to the surface structure of moldavites the word *corrosion*. We have, however, good reason to introduce another term, namely, *sculpturings;* and we will give the reason later. These surface sculpturings on both sorts of moldavites are very variable and most interesting. They afford quite a new point of view in regard to the problem of the origin of these bodies, and it is accordingly worth our while to pay close attention to them. Formerly, the structure of the tektite surfaces was compared by F. Berwerth (Tschermak's *Min. Mitt.*, Wien, 1910) with the surface structure of meteorites, but with negative results. This circumstance is easily understood, inasmuch as

the basal material of tektites and the basal materials of both stone and iron meteorites are altogether different. The most detailed investigations of the sculpturings have revealed two different kinds, namely:

(1) *Macro-sculpturings,* which are easily seen; and

(2) *Micro-corrosions,* which were discovered by Hanuš and so named because they are recognizable only when they are magnified fifty times. They are of secondary nature, and more or less obliterate the first variety of sculpturings. They are due to chemical corrosion, which has occurred in the soil. This second kind of surface feature is found on specimens which are very widely distributed. On moldavites from only a few localities is this chemical corrosion missing. The corrosion is observed as small pits, of hemispherical or vermicular form. The *second* sort of form, under the heading "(2) *Fragments,*" ante, has been caused by mechanical movement. This kind of alteration of surface can easily be recognized. The surface is not shiny, and, when magnified, the sculpturings show the small triangular forms which are characteristic of chips or splinters.

The macro-sculpturings have been carefully studied and have their own systematic nomenclature. Hanuš speaks of four different concave forms; *viz.:*

(1) *Hemispherical sculpturings;*

(2) *Ellipsoidal sculpturings;*

(3) *Incisions like deep wrinkles;* and

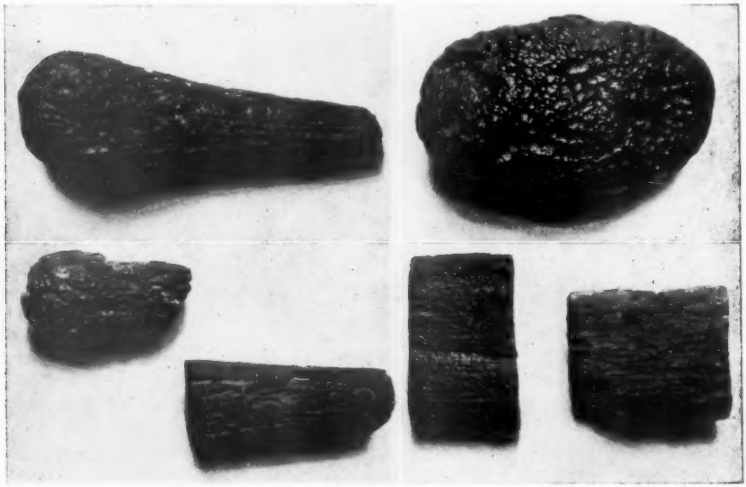
(4) *Incisions like flat or shallow wrinkles.*

These last two varieties show sharp, round, or polygonal outlines. The deep incisions are the most interesting. They show how the fragmentary and split pieces have been produced. Comparing the more than ten thousand moldavites in the collection of the National Museum of Prague, we can exactly, step by step, trace the process through which a single piece could have fallen to bits. Every special form always shows its own peculiar sculpturings.

What is the origin of these sculpturings, especially these deep incisions? In the literature will be found mainly the opinion that these corrosions have been caused by acids in the earth's crust.* In that event it is probable that the corrosions would have always the same forms. That this is not the case with moldavites is well known. The accompanying photograph (Fig. 5) shows two "partitions," as sharply cut off as by a blowtorch. This phenomenon can hardly be explained as the result of corrosion in the earth's crust. The previously mentioned parts of a gas blister (or bubble), in the form of balls, spoons, or disks, show on the convex and concave sides very different structures. Very infrequently small gas blisters (from 8 to 10 mm. in diameter) have been found, which have been cut off very sharply or have exploded in their flight through the air. In their interior these blisters show a very conspicuous concave curvature. The improbability of corrosion in the earth's crust seems to be conclusively proved by these three simple observations, all made on specimens taken from the same locality, within a space of only one square meter. The experiments of Suess also enable us to explain these phenomena of surface structure. He has studied the influence of steam on colophony, and has found that, when a piece of colophony is rotated, structures

*The frequently occurring natural glasses, *obsidians,* show very rarely, if ever, any corrosions. These corrosions can hardly be compared with the surface features of moldavites. It would be astonishing indeed if one sort of natural glasses, obsidians, showed very slight corrosions, while another sort, tektites, always showed strong corrosions.

very similar to those seen on moldavites result. In our opinion there is no likelihood that terrestrial corrosion has been responsible for these surface features of moldavites, and likewise no question that they are genuine sculpturings; hence the reason we have adopted this name for them. We may explain our point of view further, in this way: studying the fragments which we call "cut-off pieces" (see Fig. 4), we find a temporary development of the single-surface sculpturings. The place which we call the "cut-off" (see the photograph, Fig. 4) shows small sculp-



FIGURES 2-5
PHOTOGRAPHS OF CZECHOSLOVAKIAN TEKTITES (COMPLETE PIECES):
Fig. 2 (upper left): A "Drop" Form from Bohemia; Fig. 3 (upper right): A "Ball" Form from Moravia; Fig. 4 (lower left): A Sharply Cut-off "Drop"; Fig. 5 (lower right): "Partitions," very Sharply Cut Off

turings, which are more recent than the main sculpturings on the exterior of the moldavite. We are fortunate in possessing two very rare specimens of complete pieces, one in the collection of the Narodni Museum, Praha, the other in the excellent moldavite collection of Professor Oswald of České Budějovice; both of these specimens are as sharply cut off as by a blowtorch; they were found in localities a long distance from each other, and both of them show sculpturings. This fact seems to be another proof that these sculpturings originated outside of the earth's crust.

Detailed investigations have showed us that there is an important difference in shape and sculpturing between the finds in the western (Bohemian) and in the eastern (Moravian) localities. We find more round forms and sculpturings in the case of specimens from the eastern (Moravian) places. *Fragments* are not so numerous there as in the western (Bohemian) localities, where many deeply corrugated fragments have been found. The *complete pieces* have the form of elongated drops. These facts seem to prove that the western (Moravian) moldavites originated at a higher temperature than the western (Bohemian) ones and that the latter were produced from glass of a greater viscosity.

Hanuš has proposed a most interesting theory of the origin of moldavites. He is of the opinion that moldavites originated as melted material on the surface of a great meteorite. The Moravian moldavites have weights up to 150 g., and the Bohemian (if we add together the weights of the fragments), weights up to 500 g. This fact leads us to the conclusion that the parent or producing meteorite had a lower speed over the Bohemian territory, because we know that a very high speed causes the molten parts to slough off much more easily. It is supposed that the trajectory of this meteorite was nearly rectilinear, and extended in a direction from west to east. The drops which originated at a higher temperature had a greater speed than those which originated at a lower temperature. The map of the localities of the tektites (Fig. 1) shows in the Moravian territory a wedge-shaped formation.

The territory of the localities which is marked on the accompanying map has not been investigated to the same extent all over. The reason is that, roughly in the middle of the territory, are great forests and elevations, which make investigations impossible. Moreover, it is quite conceivable that the earth's crust has been inundated in these parts. Hence the reason that, until now, no moldavites have been found in this territory.

Comparison of Meteorite Falls during A.M. and P.M. Hours*

By Mohd. A. R. Khan,
Begumpet, Deccan, N. S. R., India

It is generally held that more meteorites fall between noon and midnight than between midnight and noon. Statistics (however incomplete) confirm this view. On p. 45 of his book, *Meteorites* (Chicago, 1915), O. C. Farrington discusses the hours of fall of 138 meteorites from Haidinger's table and gives the total number of A.M. falls as 57 and of P.M. falls as 81. Taking the earth's orbital velocity as 18.5 miles per second, the velocity of meteorites moving in parabolic orbits as 26.2 mi./s., and assuming, with Lowell, that the velocity produced by the earth's attraction on meteorites varies between 2.7 and 0.5 mi./s., we find that the resultant velocity of a meteorite with orbital velocity opposite to that of the earth may be as high as 47.4 mi./s., and of one overtaking the earth as low as 8.2 mi./s. It has, therefore, been supposed by H. A. Newton, W. H. Pickering, and others that the greater speed of meteorites that reach the earth's atmosphere, between midnight and noon, is responsible for heating them up to such a high temperature that all but the largest are burned up. Similarly, the smaller speed of meteorites that enter our atmosphere between noon and midnight causes less heat, and so they fall in larger numbers onto the earth's surface before they are consumed in the air.

It occurred to the writer that, if the resultant velocity of meteorites is mainly responsible for this difference between frequencies of A.M. and P.M. falls, an examination of more up-to-date data concerning hours of fall and masses of meteorites should lead to similar conclusions. Not having access to a more complete list —if there be any such available—he made use of the Appendix (pp. 141-232) at the end of Professor H. H. Nininger's *Our Stone-Pelted Planet* (1933), which extends the records up to 1932 January 1, and deduced the following results:

Hours	1	2	3	4	5	6	7	8	9	10	11	12
A.M. Falls	6	2	3	4	9	6	15	20	17	16	20	37
P.M. Falls	19	23	32	42	28	20	15	21	13	8	10	9

These results are plotted in the accompanying graph (Fig. 1). It will be seen

*Read at the Fifth Annual Meeting.

that the maximum number of falls, 42, occurred at 4 P.M. (really between 3:30 and 4:30 P.M.). Next in order, 37 occurred at noon. In P.M. hours, there is another maximum, at 8 o'clock, with 21 falls. At 8 A.M. also, there is a maximum with 20 falls. Furthermore, there have been 30 falls from midnight to 6 A.M.; 125 falls from 6 A.M. to noon; 164 falls from noon to 6 P.M.; and 76 falls from 6 P.M. to midnight.

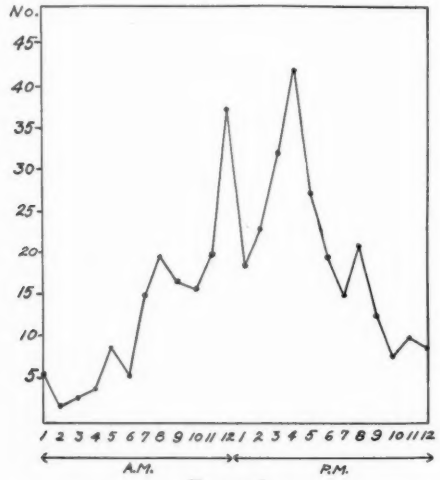


FIGURE 1

THE FREQUENCIES OF METEORITE FALLS PLOTTED AGAINST THE HOURS OF DAY AND NIGHT.

The following table has been prepared (from the same Appendix) to show the average *masses* of meteorites seen to fall in A.M. and P.M. hours, respectively, for various countries and for the earth as a whole:

Country	No. of Falls	Average Mass per Fall in Kg. in A.M. Hours	No. of Falls	Average Mass per Fall in Kg. in P.M. Hours
U. S. A.	17	40.6	42	45.3
Canada	0	0.0	3	11.0
Central America	3	1.7	3	2.0
South America	4	18.4	2	3.0
British Isles	4	15.1	10	6.4
France	11	12.3	28	28.0
Spain, Portugal, Belgium, Holland, Denmark, and Switzerland	8	30.5	11	3.9
Germany	4	4.2	16	8.1
Central European States	14	17.3	20	64.1
Italy	9	3.2	8	35.2
Norway, Sweden, and Finland	1	14.0	11	42.7
Russia and the Baltic States	11	7.9	21	60.9
Greece, Turkey,				

Country	No. of Falls	Average Mass per Fall in Kg. in A.M. Hours	No. of Falls	Average Mass per Fall in Kg. in P.M. Hours
Syria, and Persei	0	0.0	1	54.0
Siberia	3	87.0	3	6.9
Indo-China	1	53.2	3	4.7
India	37	10.1	44	6.7
Japan	6	29.3	4	17.4
Java	2	95.4	4	12.4
Africa	10	22.0	8	7.9
Arabia	0	0.0	1	4.0
Australia and Tasmania	1	11.4	1	4.4
Miscellaneous	1	3.0	0	0.0
	Total No.: 147	19.6 kg.	Total No.: 244	28.1 kg.

In the list of A.M. falls in the foregoing table, the Podkamennaya Tunguska, Siberia, iron, which fell, doubtless in masses, on June 30, 1908, at 7 A.M., and is estimated at 40,000 tons,* has been omitted, since this fall was a very rare event, nor has the great meteorite of Bezerros, Pernambuco, Brazil, recorded to have fallen in 1915 (with an estimated mass of 20 tons), been counted. Thus the records show that not only do the P.M. falls, on the whole, exceed the A.M. falls numerically, but the former exceed the latter quantitatively, as regards the average amount of mass.

In adopting the view that the majority of the A.M. meteorites, because of their greater velocities, are either consumed in the air or fall in much reduced masses, we should be prepared to find *more frequent and also more brilliant fireballs* in A.M. hours than in P.M. hours, if, as may safely be assumed, the amount of meteoritic material is uniformly accessible to terrestrial attraction. The writer is not in a position to judge whether fireball records actually confirm these deductions. Perhaps the records of the American Meteor Society and other similar organizations may furnish ample data about fireballs, concerning their hours of appearance, luminosity, height, and velocity. An examination of these records, if available, should easily settle the matter, unless the human factor to respond more to P.M. than to A.M. apparitions affects these observations also.

Perhaps it may not be out of place here to state that the Arabian encyclopedist, Ibn al-Jauzi (born 1114 and died 1201 A.D.), in his great work *Muntazam*, records 15 very bright fireballs that were observed at Bagdad and the surrounding country, between April 25, 925, and July 5, 1060 A.D. Eight of these are reported to have appeared in P.M. hours and only 2 in A.M. hours. One of each group is said to have looked "as bright as the sun." The times of appearance of the remaining five are not given. These are described in detail by the present writer in *Jour. Osmania Univ.*, **3**, 45-6, 1935.

It is natural to assume a common origin for the small meteorites in flight, which never reach the earth's surface, and fallen meteorites. Even though the spectroscope may eventually reveal the same composition for both kinds of bodies, there must be a vast difference in their masses. The former variety, it is deduced, are mere specks of stone or metal, weighing only a minute fraction of a gram; whereas the latter, even if the gigantic masses that have fallen in bygone ages, or have visited us occasionally in recent years, are excluded, weigh, on the average, several kilograms. It must be remembered also that these latter masses constitute

*[See paper by L. A. Kulik, *C.S.R.M., P.A.*, **45**, pp.559-562, Dec., 1937, next to the last paragraph.—ED.]

rarely the entire parent bodies which produce the meteors that proclaim their fall. That there is no connection between meteoritic falls and rich meteoric showers has come to be regarded now as an established fact. Further investigation may bring out still more important differences between the small meteorites which never hit the ground and fallen meteorites, and thus help us to a better understanding of both varieties of bodies.

It goes without saying that this paper could not possibly have been written had it not been for the great pains which Professor Nininger must have taken in preparing his exhaustive list of meteoritic falls (*op. cit.*). The help derived from this list is duly acknowledged.

1937 May 4

Introducing the Term Meteoritelet

While an effort should be made to keep the number of technical terms in a new science like meteoritics at a minimum, there is, we have found, a real need for a word to differentiate the many millions of small meteoritic bodies, which are wholly consumed in flight in the earth's atmosphere, from the relatively rare and ponderous kind which reach the ground and are called *fallen meteorites* or simply *meteorites*. Hence we propose the word *meteoritelet* and the following definition of it:

Meteoritelet: A meteorite which is entirely vaporized in flight in the earth's atmosphere (and, by extension, any cosmic mass which would be so vaporized), now often but incorrectly called a *meteor*, that being technically "the *light phenomenon* caused by a meteorite's [or a meteoritelet's] entering the earth's atmosphere from space."

The new term *meteoritelet* is offered in the interest of clarity and also in the hope that it may prove useful to workers in meteoritics and meteoric astronomy.

—F.C.L.

A Brilliant Fireball

About 3:55 P.M., Friday afternoon, December 10, I observed a very large meteor crossing the sky, moving from the southwest in an easterly direction; it looked like a large dirigible in flames, green balls of fire streaked from it. It was not very high above the horizon, only about 25 degrees. This was probably a very large meteor exploding as it traveled in the earth's atmosphere, but too far away for the explosions to be heard in this vicinity. It was visible about three to four seconds when it faded out on the eastern horizon.

Amsterdam, New York, December 13, 1937. M. RASMUSSEN.

A Daylight Meteor

A large daylight meteor was seen by the writer this afternoon, at 4:15 P.M. Eastern Standard Time, moving from south to north across the western sky, at a shallow angle of apparently less than 15 degrees to the horizontal. It was bright green in color, showing up brilliantly against the western sky. It appeared almost due west, and moved north slowly, through about 30 degrees, before disappearing. It was in sight for about 20 seconds, and disappeared at a point well above the tops of a row of elms situated about 500 feet from the second-floor window at which I was sitting.

Shortly after it appeared, the meteor developed a brilliant white train or track only slightly dimmer than the head. This lengthened to about 5 times the appar-

ent diameter of the head and broke into a chain of shorter streaks before fading out. A little over two-thirds of the way through its course, the head separated into two parts of apparently equal size, both of the same bright green. The two separated in the line of flight by about twice the apparent diameter of either, and both disappeared within a fraction of a second of each other at the termination of the meteor's flight.

Its green color and extreme brilliance, which was comparable with the landing lights of an airplane moving at the same apparent altitude, made it a very striking object.

P. SCHUYLER MILLER.

Schenectady, New York, December 10, 1937.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

The Backward-Moving Orbit of u *Herculis:* Few eclipsing binaries have been so well observed as the sixth magnitude star u Herculis. In a period of 2.051 days, its light curve shows two minima, and also measurable ellipticity and reflection effects.

About fifteen years ago three photoelectric curves were made to study the finer points of the variation, and it was then found that there is inconsistency between photometric and spectroscopic results. To examine this suggestive discrepancy W. J. Luyten has rediscussed the spectroscopic observations; and Calder and Shapley, to examine the suspected changes in light variation at Harvard, obtained and discussed in 1934 a new photoelectric light curve, using the Wyeth reflector at Oak Ridge.

The supsicion that the eccentric orbit is turning in space was verified by the new work, and also it was found that the orbit turns backwards, that is, that the line of apsides regresses. In other instances of apsidal rotation among eclipsing binaries the orbit turns in the same direction as the stars move in the orbit.

In a recent Harvard Circular Dr. Shapley again studies u Herculis on the basis of a new (1937) photoelectric light curve, made by Dr. Calder with the 20-inch reflector at Oak Ridge. The regression of the apsides is pretty clearly shown in two ways—by the shift of the secondary from the midpoint between primary minima, and by the variation of the reflection effect. Both phenomena must be combined with measures of the relative widths of primary and secondary minima to show apsidal regression instead of progression. Notwithstanding the high accuracy of the photoelectric curves, the quantities sought are near the limits of accuracy of the measures. It turns out that the eccentricity of the orbit is very small, possibly not larger than 0.015; and the orbit rotates in a period of about 18 or 20 years.

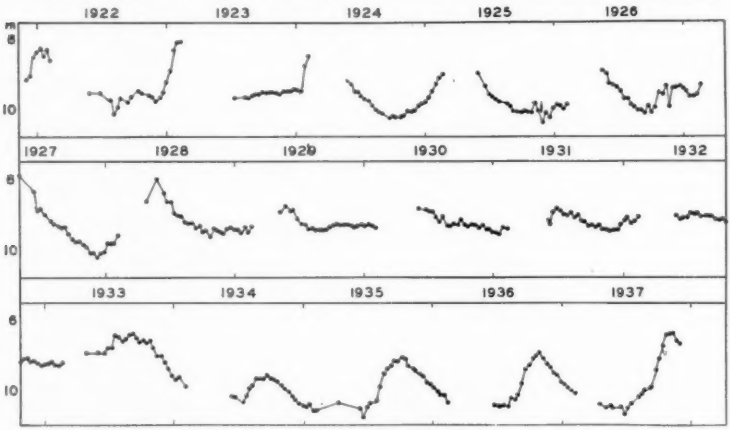
According to a somewhat preliminary discussion the apsides should progress when the component stars are well separated and spheroidal; but when they are ellipsoidal in form, through their mutual gravitational pull, the apsides regress. The components of u Herculis are slightly ellipsoidal and the new results are therefore a verification of the theory. From further studies of this kind it is

hoped to learn something more of the distribution of mass and density within the stars, for it is known that the speed of apsidal motion depends on the degree of concentration of matter towards the center.

The variable u Herculis was suspected of variation by Schmidt as early as 1848 and definitely announced as variable in 1869. It was at first thought to be of the irregular type, with a period approximating 40 days, but later, when it was found that the star was a spectroscopic binary with a period of 2.05 days, the true character of its variation and length of period was revealed. The light curve is of the Beta Lyrae type, with principal and secondary minima differing in depth by about a third of a magnitude. This star appears to be the first of the eclipsing binaries for which a regression of the apsidal motion has been found.

R Aquarii: The 1937 maximum of R Aquarii, just recently attained, reached a mean magnitude of 6.8, the brightest since that of 1933. The maximum of 1934 proved to be exceptionally faint, barely attaining the 9th magnitude, while those of 1935 and 1936 reached 8.2 and 7.9, respectively. The brightness during the last three minima was approximately of the eleventh magnitude, much fainter than at any other minimum since 1922.

It rather looks as if R Aquarii is now behaving as a regular long-period variable should, and as was the case prior to 1919. During the years 1929 to 1933, inclusive, this star behaved very erratically with an observed range hardly exceeding a magnitude or two; this in contrast to the usual range of five magnitudes.



LIGHT CURVE OF R AQUARII
1922-1937

Dr. P. W. Merrill of the Mount Wilson Observatory has studied this star from a spectroscopic standpoint and finds that it is involved in a gaseous nebula and that there is some evidence of a variable companion, similar to that found for Mira (o) Ceti.

Fortunately this variable is so situated that it can be observed both in the southern and northern hemispheres, and it should be the aim of observers to secure estimates of the star for as long a period as possible before it becomes involved in the sun's rays.

The accompanying diagram illustrates the light curve of R Aquarii for the

years 1922 to 1937 inclusive. Most of the gaps in the curve occur at a time when the star was unfavorably placed for observation.

Variability of Eros: The well-known, small planet, Eros, is again in a favorable position for observation; during January, 1938, it will attain its greatest brilliance. The computed magnitude for the middle of January is 7.6, although recent observations indicate that the asteroid is actually a magnitude fainter than the computed value.

There are several good and sufficient reasons for observing Eros during January and February, not only to check the difference between observed and computed magnitudes due to change in the phase angle, but also to determine the extent of the short, rotational period. There appears to be some controversy as to whether the asteroid rotates from east to west or vice versa. By determining the amplitude of variation as the planet rotates on its axis, it should be possible to detect the position of the planet's north pole. Several determinations of the value have already been made from data obtained up to 1935, but there is wide variance in the figures, ranging from 18°.3 for α_0 and 31°.3 for δ_0, as determined by Zessewitsch, to corresponding values of 316° and 51°, by F. Watson.

Zessewitsch maintains that the rotation of Eros is direct—West to East—and not retrograde as claimed by Watson. Zessewitsch also states that the direction of the rotation axis does not remain constant but is subject to considerable change.

Accordingly, accurate observations of the variability in light of Eros are especially desirable during the approaching weeks and, for large and powerful telescopes, observations of the position angles of the elongated body of Eros (assuming, as has been claimed, that the asteroid is of this shape) are much needed.

A four-day ephemeris of Eros is here given with approximate positions for the epoch 1938, as well as for 1855, the latter being the epoch of the Bonn Durchmusterung charts. Suitable stars for companion purposes will doubtless be found along the path of the asteroid.

POSITIONS OF EROS

Date	1938 R.A.	1938 Decl.	Computed Magnitude	1855 R.A.	1855 Decl.
	h m s	° ′		h m s	° ′
Jan. 2	3 54 54	+49 10	7.7	3 48 50	+48 56
6	4 0 27	+46 11		3 54 32	+45 57
10	4 7 20	+43 00		4 1 34	+42 47
14	4 15 23	+39 40		4 9 44	+39 28
18	4 24 20	+36 16		4 18 51	+36 5
22	4 34 2	+32 51	7.6	4 28 40	+32 41
26	4 44 18	+29 28		4 39 3	+29 19
30	4 55 3	+26 10		4 49 56	+26 2
Feb. 3	5 6 10	+23 1		5 1 10	+22 55
7	5 17 34	+20 2		5 12 39	+19 57
11	5 29 11	+17 14	7.8	5 24 22	+17 10
15	5 40 54	+14 38		5 36 10	+14 36
19	5 52 41	+12 15		5 48 2	+12 13
23	6 4 31	+10 4		5 59 57	+10 5
27	6 16 21	+ 8 5		6 11 50	+ 8 7
Mar. 3	6 28 12	+ 6 17	8.4	6 23 46	+ 6 20

Observations for November: Observations were received during the month of November, 1937, as follows:

Observer	Vars.	Observations	Observer	Vars.	Observations
Ahnert	32	185	Ashbrook	10	23
Ancarani	19	39	Atchison	1	1
Andrews	4	4	Baldwin	113	180

Observer	Vars.	Observations	Observer	Vars.	Observations
Ballhaussen	17	27	Knott	10	10
Bappu	30	49	de Kock	43	233
Benini	2	8	Kozawa	23	92
Blunck	66	71	La Fon	39	50
Bouton	84	123	Loreta	94	278
Brocchi	30	67	MacCalla	5	7
Brown, F. B.	1	2	McLeod	34	122
Brockmeyer	7	10	McNabb	3	4
Buckstaff	17	19	Meek	25	126
Callum	7	13	Millard	32	66
Carpenter	160	430	Monnig	12	13
Chartier	20	23	Murphy	14	17
Cousins	13	50	Peltier	196	228
Dafter	8	26	Pursell	1	1
Diedrich	2	5	Recinsky	11	26
Ensor	56	105	Rosebrugh	12	58
Escalante	73	90	de Roy	18	67
Evans	25	67	Ryder	22	22
Fairbanks	7	9	Schattle	5	55
Fernald	7	22	Seely	7	18
Focas	112	134	Shafer	4	10
Franklin	23	29	Shultz	17	17
Gregory	84	97	Sill	89	105
Hartmann	162	310	Smith, F. P.	28	47
Herbig	67	94	Smith, F. W.	3	11
Hiett	16	50	Smith, J. R.	33	37
Hildom, A.	36	89	Smith, L.	13	14
Houghton	62	153	Topham	9	10
Houston	169	742	Treadwell	41	110
Howarth	11	12	Walton	9	18
Humbert	4	4	Webb	48	50
Jones, E. H.	127	480	Woods	13	38
Kearons, Mrs.	5	9			
Kirkpatrick	22	75	73		5960

December 18, 1937.

Comet Notes

By G. VAN BIESBROECK

Nine comets have been under observation in the course of 1937. The following table lists the objects found:

Designation 1937	Date of Discovery 1937	Discoverer	Location	Mag. at Discovery	Character
a	Jan. 31	Simizu	Tokyo	13	Periodic Daniel
b	Feb. 7	Whipple	Harvard	12	Nearly parabolic
c	Feb. 27	Wilk-Peltier	Cracow-Delphos	7	Nearly parabolic
d	Apr. 30	Cunningham	Harvard	13	Per. Grigg-Skjell.
e	May 6	Van Biesbroeck	Yerkes	15	Per.Schwass.-Wach.
f	July 4	Finsler	Zurich	7	Nearly parabolic
g	Aug. 4	Hubble	Mt. Wilson	13.5	Nearly parabolic
h	Sept. 3	Jeffers	Lick	18	Short per. Encke

To this list should be added the faint COMET 1935 *d* (VAN BIESBROECK) observations on which have been continued through the year. But one object reported as discovered by Gale on April 6 remained unconfirmed. Some of the ob-

jects listed above have been identified on plates taken before the date of first discovery. Of all these comets only one became visible to the naked eye, namely 1937 *f* (FINSLER) which was quite conspicuous for northern observers during the months of July and August.

At present only 1935 *d* is favorably placed but it requires powerful telescopes to be recorded. PERIODIC COMET 1937 *h* (ENCKE) is fairly bright but so close to the sun that only southern observers might record its presence in January. It was recorded here last on December 1. In the evening sky it appeared as a round coma of total magnitude 7.

A return of PERIODIC COMET 1927 VI (GALE) is expected this spring. The following search ephemeris by Sumner (*Handbook of the British Astronomical Association*, 1938) will help to recover it. After an interval of ten years it is expected to return to perihelion next April, but it is probably quite faint yet at this time:

1937	R.A. h m	Decl. ° ′	Variation for Perihelion one day later m	′
Jan. 6	15 7.8	— 9 52	−1.6	+12.0
14	15 29.9	11 37	1.8	12.5
22	15 53.6	13 20	2.0	12.9
30	16 19.1	15 1	2.2	13.1
Feb. 7	16 46.5	16 37	2.5	12.9
15	17 16.1	18 5	2.7	12.2
23	17 47.8	19 22	2.9	11.0
Mar. 3	18 21.7	−20 22	−3.1	+ 9.1

Williams Bay, Wisconsin, December 20, 1937.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Astronomy and Charles II

In the year 1671 the first observatory, to use the word in its modern sense, was completed at Paris, having been four years in building, under the patronage of the "Grand Monarch," Louis XIV. I say "in its modern sense" because while there had been observatories before that, notably Tycho Brahe's at Uraniborg, they had not included telescopes in their equipment. By 1671, however, the telescope had come into quite general use,—[we have seen that] King Charles II had one ten years previously, or as early as 1661; and there was one in the Paris Observatory, presided over by the great Cassini. Here is where the French made their mistake: their observatory came first and they could have taken the meridian of Paris for THE meridian, so that today the International Date Line and Standard Time would depend upon Paris rather than Greenwich. (I believe Professor Young states that the French calculate longitude from the meridian of Paris but the rest of the world from that of Greenwich.) In his address before our Society at the last annual meeting in May, 1936, Mr. James Stokley of the Fels Planetarium, Philadelphia, showed views of both these great observatories, and said that the one at Paris had been allowed to lapse, somewhat, that the instruments and build-

ings were not kept right up, but that this was not true of the one at Greenwich.

Mr. John Flamsteed, a young mathematician who was also interested in astronomy, tells us that in 1675 a Frenchman named le Sieur de St. Pierre arrived in England with the intention of interesting English scientists in a new method which he had evolved for figuring longitudes. This method depended upon the positions of the fixed stars being known with absolute accuracy. Mr. Flamsteed, being made a member of the Committee appointed to investigate the Frenchman's method, submitted reports to show that that method could not be adopted, on account of the poor status of observational astronomy, which had failed to establish accurate positions for the fixed stars. The Frenchman appears to have faded from the scene, because no more was heard of him; but Mr. Flamsteed learned that his reports had been brought to the attention of the King who had become quite excited on reading them, and had at once declared that he "must have those positions observed anew and examined and corrected for the use of his seamen."

Thus we see that it was really for the benefit of navigation that the Observatory was established at Greenwich; and the same is true of the one at Paris.

It was just at that time that great men, great, that is, in the sense of holding exalted rank and position, were beginning to show interest in science. The King himself was genuinely interested in astronomy; as was his cousin, Prince Rupert, in chemistry.

A Royal Observatory was decided upon, and several different sites were discussed, including Chelsea and Hyde Park. The King enlisted the services of Sir Christopher Wren, who cast his vote for Greenwich. We are told that Sir Christopher was a very short man; the King a very tall one; they must have looked comical going around together, looking at sites. "The long and short of it" so to speak. The King supplied a grant of five hundred pounds, and in addition provided bricks from Tilbury Fort, and iron, lead, and wood from an old gateway which was then being demolished at the Tower. The corner stone was laid on August 10, 1675, and Mr. Flamsteed was appointed First Astronomer Royal, (with a salary of one hundred pounds a year, and without an assistant). Had the King done nothing more than that for the cause of astronomy he would still be entitled to our gratitude. It is to John Flamsteed that we owe the first reliable catalog of stars. It seems that in 1690 he plotted accurately on his charts the position of the planet Uranus, but did not recognize it as a planet; on account of its slow motion he mistook it for a star, thus escaping, by ninety-one years, the fame which afterwards came to Sir William Herschel for his great discovery: but we must remember that Sir William, himself, did not at first recognize it as a planet but for some months after its discovery believed the fuzzy object he had sighted through his telescope to be a comet. Flamsteed's fame is secure, however, not only by reason of his star catalogs but from the fact that a crater on the moon is named for him.

Mr. Flamsteed was a short-tempered man, who took strong likes and dislikes. He abhorred Sir Isaac Newton and all his works, but the object of his special dislike was Sir Isaac's ardent admirer, firm friend and devoted disciple, to whose generosity we owe the publication of the "Principia,"—Mr. Edmund Halley. When, in 1720 or 1721 (both dates are given), Halley, having been appointed Second Astronomer Royal on Flamsteed's death in 1719, went to take possession of the Observatory, he found everything in very bad shape, many of the instruments in poor condition, and the best ones "among the missing" as they had been carried away to Flamsteed's own home. That was all well enough, as most of them had been purchased by Flamsteed with his own money; but the widow refused to turn

them over to the man who had been the object of her late husband's hearty dislike; so that Halley began his work at the Observatory quite heavily handicapped.

He was of an entirely different type. He preceded Sir John Herschel in a study of the southern stars, landed at St. Helena to make observations long before Napoleon's exile there. He worked for a while at the Paris Observatory with the great Cassini. In 1678 through the influence of King Charles he was made Master of Arts at Oxford and joined the Royal Astronomical Society that same year. In 1705 he read a paper before that Society predicting the return of the great comet which bears his name, in 1758; adding that he would not be alive to see its return but that if it did come back, he hoped posterity would not forget that its return had been predicted by an Englishman. Posterity did more than that; it promptly bestowed his name on the great comet with a period of 75 or 76 years; the only instance of a comet being named not for its discoverer but for the one who had predicted its return.

In the year 1682, the year of Prince Rupert's death and three years before the King's death, the whole world was looking at a great comet, flashing in the evening sky. Mr. Halley conceived the idea that it might be not a first appearance but rather a return engagement for the comet. He traced it back through history to the year of the Norman Conquest, 1066, and even farther back into Chinese records, becoming convinced that it was the same comet with a periodicity of 75 or 76 years.

In 1716 Halley evolved a method of figuring more accurately the distance of the sun from the earth by observations of the transits of Venus. In 1718 he discovered "the proper motion" of stars,—*i.e.* their shift of position with relation to other stars in the neighborhood; and also the slow motion of the star Sirius; which led to the discovery in our own time of the Companion of Sirius by Alvan Clark, Jr.

So much for Astronomy and Charles II; historians and biographers assure us that the King's soul, if indeed he ever had one, is lost from here to eternity; but he had his own private telescope, and I believe a beautiful star was named for him, which must be some consolation. Some of us may have stood before his neglected grave in Westminster Abbey. A small white stone marks the spot. It seems to be toppling over, being inclined at some 23½ degrees from the plane of the perpendicular; or so it was when I saw it in 1913; it may have been straightened since.

But Charles should worry; he has a better monument, one which will endure so long as men walk this earth of ours or sail its seven seas. I refer to the International Date Line and the Naval Observatory at Greenwich. That is quite prominent; we see it as we come down the Thames; like "Kew in lilac-time" "it isn't far from London"; in fact Greenwich may now be considered a suburb of that great city. Here is how a recent traveler on the River of London, Mr. Marc T. Greene, describes, in a letter to the Providence Sunday "Journal" of August 23, 1936, what is Charles' true monument.

"*Green Lawn Marks Famous Meridian.*—Now we come to Greenwich and the Royal Naval College. A broad green lawn between the buildings marks the famous Meridian, Greenwich Mean Time. Well, here it is, the place where the standard time of all the world is determined, the time from which all others are reckoned and to which 10,000 chronometers are set. Somewhere in the South Seas, Longitude, 152 degrees, 37 minutes, West of *Greenwich*. In the middle of the Indian Ocean, Longitude 74 degrees, 19 minutes, East of *Greenwich*. Greenwich and the Royal Observatory, whence Capt. Cook sailed on the Royal Society's ex-

pedition to note the transit of Venus, in Tahiti, and to give that romantic island group its name." (That transit expedition, I might add, was financed by King George III out his own pocket, and is the same transit which was observed here in Providence in the vicinity of Transit Street by Benjamin West (NOT the great artist) *et al* on June 3, 1769.)

In "Vanity Fair" Miss Horrocks tells Hester, the little maid on her promotion who persists in addressing Miss Horrocks as "Your Ladyship" that "There has been better ladies and there has been worser, Hester." Doubtless "there has been better" Kings than Charles II and possibly "there has been worser"; but not one of the whole lot, whether "better" or "worser" has done anywhere nearly as much for astronomy as did (though perhaps unwittingly) this graceless seventeenth century sovereign. Therefore, not only tonight but each and every night to the end of the world, Urania, Muse of Astronomy, makes a grateful little bow to that royal rascal, His Majesty King Charles the Second; and so may *we*.

V. E. Atwell.

33 Ridge Street, Arlington, Cranston, Rhode Island. February 8, 1937.

Notes from Amateurs

Amateur Astronomical Society of New Haven

The New Haven Amateur Astronomical Society at their meeting on November 20 listened to a report from the Meteor Observing group regarding their observing of the Leonid shower in which ninety-six meteors were observed and charted. This work was done in conjunction with similar groups at Vassar College, Smith College, Providence, and Norwalk.

Mr. Knapp gave an interesting talk on Orion.

Mr. Ralph Partridge of the New Haven Power Squadron addressed the meeting, his subject being "Navigation." He reviewed the conditions met with by Columbus in 1493 when his vessels were returning from the New World, steered according to a crude magnetic compass, the speed estimated by chip log, and the time being kept by a sand glass. Columbus found to his dismay that his compass seemed to wander slightly when compared with the North Star. While the horizon was visible he made observation with a crude instrument called a cross-staff and with a few computations he obtained his latitude. But what of his longitude, that was a problem beyond the power of living man, and was not solved until nearly three hundred years later. The best he could do was to estimate his easting by dead reckoning and meanwhile his ship was running blindly and the distance to the nearest land unknown.

In contrast to the above the speaker reviewed the work of a modern navigator, observing the stars of early morning, several shots at the sun at different times including the meridian passage, more observations of sun and moon if visible in the day time, again in the evening more stars and planets, and at each observation the exact time is recorded on his chronometer running on Greenwich Time. His chronometer is repeatedly checked by radio signals, his ship is being steered by a mechanical "Mike" controlled by a gyrocompass which knows nothing of magnetic declination. In addition he continually receives reports concerning the weather in various places and the position of ships bound both east and west. He works in a well-lighted chart room fully equipped with accurate charts and plotting sheets with nautical almanacs giving the position of the various celestial objects he has

been observing. In a few minutes of calculation of a simple nature he plots the position of his ship with a possible error of one or two miles under normal conditions.

The progress in the science of navigation was largely in the development of nautical instruments. Up to 1730 the determination of latitudes was just as likely to be inaccurate as it was to be accurate, due to the fact that the instruments were so crude. In 1730, John Hadley, in England, and Thomas Godfrey, in Philadelphia, by a peculiar coincidence invented the reflecting sextant as used today, making it possible to obtain an accurate measure of angles between the celestial body being observed and the horizon without the observer having to look in two directions at once as was necessary in the early instruments. Still the problem of finding longitude was not solved and many ships were lost because of this fact, as any error in estimating the speed of the ship made the reckoning valueless. It was not until 1761 when John Harrison of England developed an accurate timepiece or chronometer that the correct longitude could be determined, as the difference in longitude between two places is nothing more than the difference in time.

One degree equals four minutes of time, and one minute of longitude is equal to four seconds of time, therefore to determine the difference of longitude of two places it is only necessary to know the local time at the two places for any given instant and the difference between these times when converted to an arc, will be the difference of longitude.

Many other aids to navigation have since been developed so that our modern ship can find its way across the ocean with great accuracy.

Mr. Partridge's speech was well received as was indicated by the many questions asked.

F. R. BURNHAM, *Secretary.*

The Cleveland Astronomical Society

On Friday evening, December 3, our members and friends gathered at the Physics Lecture room, Case School of Applied Science. Subject, Cosmic Rays, and speaker, Dr. Robert Shankland of Case School. We heard how cosmic rays are observed, what they are, and what is their origin. We also saw in operation the instruments by which they are observed. The subject is the special field of study of the speaker. Our President, Dr. Nassau, made the arrangements for this splendid lecture and demonstration by Dr. Shankland. The society is much indebted to Case School for their generous help to our group.

The publication of a list of books on Astronomy sponsored by our society is finished and the lists are in the hands of our members. To Miss Helen Focke, we are indebted for the greater part of the preparation of the list, and to Mr. George Hale for the task of printing. This is a very valuable list for anyone interested in astronomy. Distribution is through the Cleveland Public Library.

DON H. JOHNSTON.

14 Lincoln Drive, Cleveland, Ohio.

Wisconsin Observers

A small group of amateur astronomers, mostly A.A.V.S.O. observers, are launching a new club in Milwaukee which will be called the "Wisconsin Observers." Membership is restricted to individuals doing some kind of active observational work in variable star, meteor, asteroid, or photographic work. The club grew out of a feeling of need for an organization which would better diffuse ob-

serving techniques, and bring about greater realization that much of value can be done in planning coöperative observing programs so that much of the needless duplication now evident in A.A.V.S.O. circles can be eliminated. We look forward to coöperative observing programs so arranged that the greatest amount of work of the greatest value will be obtained. Observers in Milwaukee and the surrounding region who are interested in joining in such a program will be gladly welcomed. Such individuals should address their communications to

WISCONSIN OBSERVERS,
Station F, Box 176, Milwaukee, Wisconsin.

General Notes

Raymond S. Patton, Director of the United States Coast and Geodetic Survey, died at his home in Washington, D. C., on November 25.

Dr. Annie Jump Cannon, curator of astronomical photographs at the Harvard College Observatory, received the honorary degree of doctor of science at the Mount Holyoke Founder's Day exercises, which marked the completion of the first hundred years of the college. In this connection Dr. Cannon made an address entitled "Stars Over the Sea." (*Science*, November 26, 1937.)

Dr. G. W. Moffitt, formerly of the Yerkes Observatory, has become a member of the Perkin-Elmer Company. The new firm will operate under the name of Perkin, Elmer, and Moffitt Company. This firm specializes in optical design and consultation. It also is distributor for telescopes and optical instruments of precision of all kinds.

The Aurora Borealis on November 30, 1937

The display was first seen at 7:35 P.M. (E.S.T.) and the last portion was seen, followed only by the low glow along the horizon, at 7:55 P.M. The display took the common form of streaks like the folds of a curtain, centered at about 15° west of north, and extending about 45° along the horizon. The colors, pink and apple-green, in addition to a fish-belly white, were well marked most of the time. The streamers extended to a height of about 45°, at the maximum. So far as I know, no conspicuous spots or other solar features were present at the time.

ROY K. MARSHALL.

Wilson College, Chambersburg, Pennsylvania.

Literary Inquiry

On the first page of the introduction to "Star-names and Their Meanings" by Richard Hinckley Allen published in 1899 we read "For almost all can repeat Thomas Carlyle's lament: 'Why did not somebody teach me the constellations, and make me at home in the starry heavens, which are always overhead, and which I don't half know to this day?'"

This quotation is found in several astronomical books but I know of no reference earlier than Allen's and it is probable that the others have copied the quotation from Allen. I have endeavored unsuccessfully to verify the quotation and to find the original source if possible. I have asked two experts on Carlyle about it

and neither can give its source after search and one of them doubts that it is an authentic quotation. I shall appreciate any information any reader can give.

S. G. BARTON.

Flower Observatory, Upper Darby, Pennsylvania.

Book Reviews

The Prediction and Reduction of Occultations

The above is the title of a pamphlet of 46 pages, designated as a Supplement to The Nautical Almanac for 1938. The pages are closely packed with descriptions, formulas, and tables and one must bring some acquaintance with the subject to it in order to use the pamphlets intelligently. This phase of astronomical work has the advantage that it can be carried on with small equipment, and consequently is one which appeals to the amateur. It further has the attraction that its results can be immediately useful, for the accurate path of the moon is determined by them.

These pages bound by themselves are much more convenient for use than if they were an integral part of the larger Nautical Almanac. It may be secured from H. M. Stationery Office, Adastral House, Kingsway, London, WC2.

Sunspots and Their Effects, by Harlan True Stetson. (Whittlesey House, McGraw Hill Book Co., Inc., New York City. $2.00.)

In "Sunspots and Their Effects," Dr. Stetson provides a summary of the speculation which is rife on the subject, as well as a popular presentation of some of the more established conclusions of science regarding sunspots and their effects. A table of Wolf sunspot numbers is appended.

After an introductory chapter concerning sunspots and their possible influence in producing weather cycles, business cycles, and other terrestrial effects, Dr. Stetson takes up the subject of "Sunspots and Human Behavior," a speculation on the possibility that human behavior may change according to the degree of spottedness of the sun. The critical reader would undoubtedly welcome more quantitative information, so that he could judge for himself the strength of the suspected relationships.

Chapters 3 and 4, on the relationship of sunspots to the growth of plant life, and to radio, are interestingly informative. Chapter 5 deals with the controversial subject of sunspots and business. Then follow chapters on "Measuring Sunshine," "Weather and Sunspots," "Solar Utilities, Power and Light," "Sunspots," "The Earth's Magnetism, and Carrier Pigeons," "Where Sunspots Grow," "Can We Predict Sunspots?", "What Makes Sunspots?", and "Alongside Singapore—A Résumé." Concerning "What Makes Sunspots?" the reviewer hopes Dr. Stetson will succeed in putting his theory to an analytical test. One remains a bit skeptical of the hypothesis of a "natural period of vibration of the sun's atmosphere," and of other features of the theory.

It is our feeling that Dr. Stetson has rendered a service in systematically studying and reporting to us his findings and ideas, concerning a topic about which there is bound to be difference of opinion. R.S.Z.

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